

## GULF COASTAL PLAIN ECOSYSTEM PARTNERSHIP FACTS

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<i>Partners</i>	<i>Acres involved</i>
Eglin Air Force Base	463,441
Florida Division of Forestry	189,374
Northwest Florida Water Management District	97,781
National Forests in Alabama	83,790
Champion International Corporation	7,550
The Nature Conservancy	2,750
National Forests in Florida	1,114

**In response to a dramatic loss of longleaf pine habitat across the southeastern United States, seven public and private landowners have formed a partnership and signed a Memorandum of Understanding to conserve and restore this dwindling ecosystem in the Florida Panhandle and southern Alabama.**

**The partnership grew out of the desire of local land managers to share resources in a time of dwindling funds, an increased demand for better information, resources and expertise. The managers wish to act cooperatively and to share significant challenges, such as management of endangered species, support of natural resource-related jobs and increased recreational demands.**

**The lands and waters included in the partnership are managed for different objectives. These objectives range from intensive forestry to military training, recreation, water resource protection and ecological restoration. They all share in common the longleaf pine ecosystem and the needs of local people.**

**The longleaf pine ecosystem was once the most common upland forest type in the Southeastern United States. It has declined by more than 95 percent and is now one of the most imperiled ecosystems in the country.**

**The 845,800 acres encompassed by the Gulf Coastal Plain Ecosystem Partnership contain more than 20 percent of the remaining longleaf ecosystem. Also contained within this acreage is more than 50 percent of the remaining old-growth stands of longleaf pine.**

**To date, the partners have conducted a number of cooperative efforts including:**

- Joint prescribed fires to restore important ecological areas and reduce hazardous fuels
- Coordinated siting of the Florida National Scenic Trail and other recreational amenities
- Cooperative management of the federally endangered red-cockaded woodpecker
- Information exchange on forest management techniques and technology
- Tracking the status and location of rare plants and animals

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**These connected lands include more than just longleaf pine.** They contain ecosystems that cut across geographic boundaries, portions of four major watersheds, commercial pine plantations, extensive bottomland hardwood forests, more than 160 rare or imperiled plants and animals, and important game and fish populations.

**Under the Memorandum of Understanding,** partners will develop and implement a cooperative and voluntary stewardship strategy to:

- Sustain native plants and animals
- Conserve and restore the integrity of ecosystems
- Ensure a continued supply of forest commodities, recreational opportunities, clean water and ecosystem services
- Support the human communities that depend upon these resources and services

**The partners each have different management objectives,** levels of staffing, resources and types of expertise. Partners will combine expertise and resources to more fully and efficiently meet objectives on individual properties and the challenges of managing the larger ecosystems.

**Partners will develop specific agreements** and working plans for individual projects considered to have mutual interest.

**Partners recognize the full rights** of individual land managers and neighboring private property owners to pursue their own interests and objectives on their own land.

**Partners welcome the involvement of interested private land owners** and residents in pursuing the purpose of this Memorandum of Understanding.

**The Memorandum can be amended** at any time to bring in new partners, information or other necessary changes, subject to concurrence by all partners.

**This Memorandum is in no way intended to limit or constrain** the partners' individual management objectives.

**Nothing in the Memorandum commits the partners** to additional expenditure of funds above or beyond normal appropriations or obligations.



# Gulf Coastal Plain Ecosystem Partnership

## Steering Committee Meeting # 2

Champion International Forest Genetics Research Center  
June 22-23, 1999

### Research, Scientific and General Information

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*Isolated Wetlands*  
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*Amphibians*  
*Flatwoods Salamander*  
*Other Amphibians*  
*Blackwater River*  
*Aquatic Insects*  
*General*

# Importance of Isolated Wetlands in Upland Landscapes

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Linda V. LaClaire  
Department of Wildlife and Range Sciences  
University of Florida  
Gainesville, FL 32611

Richard Franz  
Florida Museum of Natural History  
University of Florida  
Gainesville, FL 32611.

## Abstract

Perched, isolated wetlands in upland areas in the southeastern coastal plain are essential for a group of specialized vertebrates that tolerate highly variable hydroperiods. These ponds are particularly important as breeding sites for several upland amphibians with eggs and/or larvae that are vulnerable to fish predators. Several of these vertebrates are listed as declining species by the Florida Committee on Rare and Endangered Plants and Animals and/or the Florida Game and Fresh Water Fish Commission. In order to protect the ponds and their unique fauna, it is necessary to understand the role of wetland soils, specialized vegetation, and hydroperiod in the formation and maintenance of this habitat.

## Introduction

Generally overlooked, isolated ephemeral ponds are important components of upland landscapes in the southeastern United States. Their importance has been underestimated because of their generally small size and because these sites are frequently isolated with respect to one another. A high level of connectedness has been given high value in some wetland habitat evaluations with a low value given to isolated wetlands (Brown & Starnes 1983). This has led to a disregard for the unique character of these wetlands and the flora and fauna that inhabit them.

As a result of their isolation in an otherwise droughty environment, isolated ephemeral ponds are used as watering places, sources of food, and in certain cases for nesting. Snakes, turtles, wading birds and mammals frequently use these ponds. Most importantly, these wetlands are essential breeding sites for a significant number of upland amphibians, in particular striped newts (*Notophthalmus perstriatus*), mole salamanders (*Ambystoma talpoideum*), barking treefrogs (*Hyla gratiosa*), and gopher frogs (*Rana areolata*). These species have eggs and/or larvae that are vulnerable to fish predation. They are able to successfully inhabit

droughty uplands as a part of a group of specialized vertebrates that are adapted to highly variable hydroperiods. Several of these vertebrates are listed as declining species by the Florida Committee on Rare and Endangered Plants and Animals and/or the Florida Game and Fresh Water Fish Commission. In order to gain protection for this unique fauna, it is imperative that their breeding ponds are protected and the ecology of these ponds is understood.

We have recently begun a study of isolated, ephemeral ponds in three Florida counties to better understand the relationship between these wetlands and their use by amphibians. Ponds known to be breeding sites for the gopher frog (*R. areolata*) and the striped newt (*N. perstriatus*) were selected. Our study sites are contained within the Apalachicola National Forest in Leon County, the Ocala National Forest in Marion and Putnam Counties, the Katherine Ordway/Swisher Memorial Sanctuary and the Welaka Research and Education Center in Putnam County. Each study site consists of 2-6 ponds characterized as round, shallow depressions that irregularly fill with water. They are sinkhole in origin and tend to be associated with sand ridges. The ponds are surrounded by upland habitats of high pine, scrubby flatwoods, or scrub.

Isolated, ephemeral ponds support a very different plant and animal community than those found in larger, more permanent wetlands. Permanent wetlands may dry in exceptional years and in such cases, most of the permanent water fauna will be extirpated. Recolonization by fish and other permanent water fauna will only be possible when high water connects the wetland to others where the fauna is present. In temporary waterbodies, selection has occurred for species adapted to a cycle of drying and re-filling. Such an environment provides a unique habitat for plants and animals as a result of isolation and varying hydrology. For them, stability of water level is not a beneficial condition. In our study, we are looking at the role of pond soils, specialized vegetation, and hydrology in the formation and maintenance of this habitat.

At the beginning of 1990, we began an assessment of the physical and botanical aspects of our study ponds. Those holding water were sampled for amphibian larvae. Vegetation and soil were analyzed along transects within dry pond basins. From the data collected thus far, we are able to construct a preliminary picture for isolated, ephemeral ponds contained within upland habitats of north-central Florida.

## VEGETATION

The plants encountered within ephemeral pond basins reveal a range of adaptations in tolerating inundation and represent a succession that results in zonation of the vegetation (Lippert and Jameson 1964). The gradually decreasing water depth typical of ephemeral pond drying often results in zones of vegetation in concentric rings of different species and vegetative types. Both the frequency and duration of pond filling is reflected in the vegetation of the concentric bands. When the pond is filled, the inner zone often contains floating-leaved plants, then submergents, tall and short emergents at the pond edge and lastly water-tolerant shrubs or trees in some transitional zones (Weller 1978). As water levels change, the bands of vegetation move back and forth across the pond basin in a reflection of soil moisture conditions. After the pond dries, emergent grasses fill the previously flooded portion and the submergents senesce or adjust their growth to a terrestrial form.

The vegetation of the ponds we have analyzed typically form a pattern as shown in Figure 1. Maidencane (*Panicum hemitomon*) is an obligate wetland species (Reed 1988) that has been found in all of the ponds. It prefers very moist soil and thus the upslope location of the *P. hemitomon* band represents the edge of the previously flooded portion of the pond. Further upslope, a ring of sandweed (*Hypericum fasciculatum*) represents the next level of soil moisture. It is considered a facultative wetland plant in the National List of Plants Occurring in Wetlands with a probability approaching 99% of usually occurring in wetlands

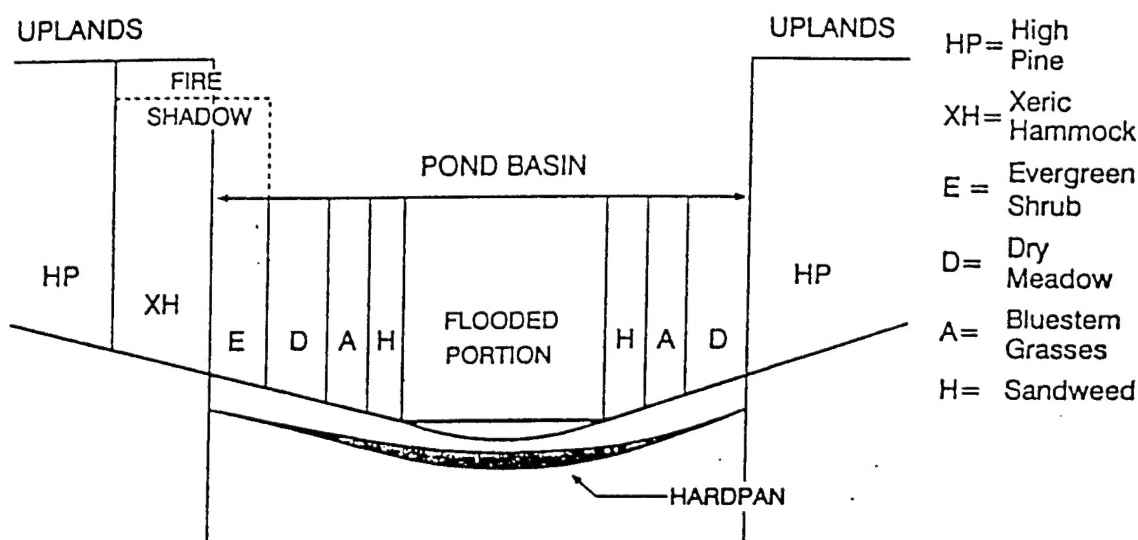


Figure 1. Vegetational structure of pond basin with associated hardpan.

(Reed 1988). This category of wetland plant requires less soil moisture than an obligate wetland species. Bluestem grass (*Andropogon virginicus*) dominates the next ring of vegetation in many of our ponds. Its status as a plant in the next level of soil moisture is reflected in a listing as a plant equally likely to be found in non-wetlands as wetlands. Continuing upslope, vegetation is found in dry meadows consisting of species occurring equally in wetlands and non-wetlands and species occurring generally in uplands. The species composition of each of our study ponds differs depending on existing soil moisture conditions, hydroperiod and surrounding upland type, but the general pattern of banding remains consistent.

An additional feature of several ponds is the presence of a fire shadow along the upslope wetland/upland boundary (Fig. 1). The vegetation within the fire shadow contains fire intolerant evergreen shrubs (*Ilex*, *Vaccinium*, *Myrica*, *Ceratiola*) and sometimes xeric oak hammock woodland zones. Ponds

that have been burned completely from upland margin across to opposing upland margin lack this vegetation. However, under certain conditions, particularly when the ponds are filled, fire will slow and burn out as it goes down slope into the depression basin. This allows invasion of less fire resistant species on the protected side.

The amount of disturbance or perturbation within the pond basin has a direct effect on the diversity and species composition of the vegetation. Human perturbations such as the use of isolated, ephemeral ponds by off-road vehicle enthusiasts tends to reduce the diversity of vegetation found in them (pers. obs.). Also, plowing into the dry meadows along pond margins can result in the invasion of other plant communities, including sand cordgrass (*Spartina bakeri*) meadows and components of xeric oak hammocks. On the other hand, our initial pond surveys indicate that disturbance by fire tends to increase the species diversity and maintain original habitat components.

## SOILS AND HYDROLOGY

The vegetation of isolated, ephemeral ponds is directly related to the underlying soils. Most of our study ponds are located in regions of sand ridges and have the sandy soils corresponding to those of the surrounding uplands. However, organic matter has accumulated in the pond basin and influenced the formation of soil surface horizons that can be classified as hydric soils. If the pond has been filled for several seasons, organic material will accumulate on top of the surface sands. As the pond alternately dries and fills, a subsurface organic hardpan can form below the top layers of sand. This is a result of leaching of organic acids from the dead vegetation above. The sand grains become coated with organic material and begin to adhere to each other. This results in a dense layer that acts as a confining bed by preventing water from draining into the sand layers below. Above and below this organic hardpan the sands are streaked with organic matter. Because of the gradual drying of ephemeral ponds and their occurrence in depressions, the center of the pond holds water longest. As a result, the accumulation of organic matter is thickest in the middle and becomes thinner towards the outer edges of the basin. The corresponding variation in soil moisture retaining capacity has a direct effect on the bands of vegetation that form as described above. Our initial soil surveys correspond with this pattern.

Hydrology is probably the single most important determinant for the establishment and maintenance of isolated, ephemeral ponds (Mitsch and Gosselink 1987). Water depth, flow patterns, and duration and frequency of flooding all influence the biochemistry of the soils and the ultimate selection of the biota. Precipitation is the most important source of water for these wetlands. The amount of precipitation required to re-fill a pond once it has dried depends on the amount of soil moisture, the permeability of the hardpan and the slope of the surrounding pond basin. The more saturated the soil, the smaller the input of rainfall is required to refill a pond. If an organic hardpan has formed, it will maintain soil saturation for a longer period of time.

As the pond fills, there is a pulse of primary productivity as nutrients enter the system. Flooding the soil can also increase the availability of nutrients; phosphorous has been shown to be more soluble under anaerobic conditions (Patrick and Khalid 1974). Over time, plants within the pond basin grow and senesce. Organic matter accumulates on the pond bottom because of slowed decomposition under anaerobic conditions. But, as the pond dries, aerobic decomposers will begin rapidly breaking down the organic matter. Fungi and bacteria colonize the detritus also. Their contribution in terms of additional protein content acts to increase the nutrient value of detritus upon pond re-filling beyond that of permanent ponds (Barlocher et al. 1978). The resulting nutrients will then become available upon the next flooding event. Thus, a building up of nutrient supply occurs and through time the combination of biotic and abiotic elements enriches the pond environment.

## AMPHIBIAN USE

In the southeastern coastal plain, ten species of anurans and five species of salamanders breed primarily or exclusively in small, isolated, ephemeral wetlands. In addition, at least ten other species of anurans and seven species of salamanders utilize the habitats opportunistically as well as more permanent sites (Moler and Franz 1987). Table 1 shows the breeding habitats utilized by frogs and toads in Florida. The obligate ephemeral pond breeders cannot withstand the greater range of predation, both vertebrate and invertebrate, encountered in more permanent wetlands (Wilbur 1980). The ephemeral nature of the pond also appears to be an integral component in successful reproduction of ephemeral pond breeders. Two studies (Caldwell 1987, Pechmann et al. 1987) have shown that these amphibians were able to reproduce successfully only in those seasons when the site had dried completely and then refilled. This suggests that the increased availability of nutrients that occurs with pond filling is important in promoting rapid growth and high population densities of larval amphibians. Also, the drying of the pond eliminates possible fish and other large predators



so that when the pond fills the larval amphibians have an initial size advantage over invertebrate predators (Wilbur 1980).

Several studies have quantified the species composition and density of breeding amphibians that can be supported by very small breeding ponds. Pechmann et al. (1987) documented the metamorphosis of 75,644 juvenile amphibians of fifteen species from a 1 ha ephemeral pond in South Carolina. Wharton (1978) found that annually, 1600 salamanders and 3800 frogs and toads moved to a small (<30m diameter) gum pond in Georgia. Dodd and Charest (1988) monitored the use of an ephemeral pond (<0.2 ha) at the Ordway Preserve in Putnam County, Florida over a period of 27 months and captured 2870 individual frogs of 14 species and 1354 individual salamanders of two species.

We have been able to gain only a preliminary understanding of which amphibian species breed in our study ponds due to the current drought in the state of Florida. However, we did find larval amphibians in five of our study ponds in Leon and Marion counties in 1990. In Leon County, four ponds held water during the winter breeding season. In these we found a larval amphibian community composed of the barking tree frog (*H. gratiota*), spring peeper (*H. crucifer*), southern leopard frog (*R. utricularia*), gopher frog (*R. areolata*), southern cricket frog (*Acris gryllus*), striped newt (*N. perstriatus*), central newt (*N. viridescens*) and mole salamander (*A. talpoideum*). In addition, one of our ponds in the Ocala National Forest has intermittently held water from March, 1990 until the present (October, 1990). During March and late May surveys, larval striped newts (*N. perstriatus*) were found. When the pond was surveyed in September for evidence of late summer breeding, we found tadpoles of the frog species *H. gratiota*, *H. femoralis*, and *A. gryllus*, but no newts were present. During the ensuing study we will be able to determine a more complete list of the species using these isolated, ephemeral ponds.

## IMPLICATIONS FOR CONSERVATION

Ephemeral ponds are integral parts of upland landscapes. They contribute to ecosystem diversity by providing rich resource patches imbedded within the surrounding habitat (Laney 1988). The vegetation and soils accumulate nutrients and the ponds provide a source of water in droughty environments. As a circular patch, they provide a high interior to edge habitat ratio which may increase the species diversity and foraging efficiency of animals within the pond basin (Forman and Godron 1986). The elimination of these wetlands acts to fragment the surrounding uplands and may reduce or prevent species migration along corridors or exchange between isolated patches.

Upland amphibians rely on ephemeral wetlands and are important elements in the food chains of terrestrial predators and wetland bird species. They can contribute significantly to the biomass of terrestrial ecosystems and in some cases amphibians have been shown to be the dominant vertebrate group (Burton and Likens 1975, Gosz et al. 1978). They also represent one of the few vertebrate biotic mechanisms for the transport of nutrients out of eutrophic waterbodies and into terrestrial ecosystems (Wassersug 1975). Most species of upland amphibians (except for terrestrial breeders) are dependent on isolated ephemeral ponds for the completion of their life cycle. They are susceptible to habitat fragmentation, degradation of suitable upland sites, and most importantly to the loss or degradation of their breeding sites. Different amphibian species breed at different times of the year; therefore, multiple ponds with different filling regimes may be necessary to allow for successful reproduction of all species. Recent attention has been focused on amphibians that are declining worldwide and their potential as sensitive bioindicators of environmental change. Their decline is an indication of deeper ecosystem deterioration and decay of the food web (Blaustein and Wake 1990, Borchert 1990, Vitt et al. 1990). The disappearance of upland amphibians from the landscape also has inevitable, major consequences for other components of the ecosystem, since

amphibians form important links in upland food webs.

Future studies will focus on describing the biotic and abiotic components of isolated, ephemeral ponds. The mechanisms for pond development and maintenance are not well understood and more

information is necessary for future successful restoration or reconstruction. A greater appreciation and understanding of the ephemeral pond breeding sites of amphibians is necessary to ensure amphibian survival and the protection of the upland faunal community.

Table 1. Breeding habitats utilized by frogs and toads in Florida (modified from Moler and Franz 1987).

Species	Small Isolated Wetlands	Open Marsh	Riparian & Forested Wetlands
* Eastern spadefoot ( <i>Scaphiopus holbrookii</i> )	X		
* Oak toad ( <i>Bufo quercicus</i> )	X		
* Barking treefrog ( <i>Hyla gratiosa</i> )	X		
Squirrel treefrog ( <i>H. squirella</i> )	X		
* Pinewoods treefrog ( <i>H. femoralis</i> )	X		
* Little grass frog ( <i>Limnaeodius ocularis</i> )	X		
Ornate chorus frog ( <i>Pseudacris ornata</i> )	X		
Southern chorus frog ( <i>P. nigrita</i> )	X		
* Gopher frog ( <i>Rana areolata</i> )	X		
* E. narrowmouth toad ( <i>Gastrophryne carolinensis</i> )	X	+	
Spring peeper ( <i>H. crucifer</i> )	+		+
* Southern toad ( <i>B. terrestris</i> )	+	+	+
Green treefrog ( <i>H. cinerea</i> )	+	+	+
Gray treefrog ( <i>H. chrysoscelis</i> )	+		+
* S. cricket frog ( <i>Acris gryllus</i> )	+	+	+
Bronze frog ( <i>R. clamitans</i> )	+		+
Pig frog ( <i>R. grylio</i> )	+	+	+
Bullfrog ( <i>R. catesbeiana</i> )	+		+
* S. leopard frog ( <i>R. utricularia</i> )	+	+	+
Carpenter frog ( <i>R. virgatipes</i> )	+	+	+
Fowler's toad ( <i>B. woodhousei</i> )			+
Bird-voiced treefrog ( <i>H. avivoca</i> )			+
Pine Barrens treefrog ( <i>H. andersonii</i> )			+
Upland chorus frog ( <i>P. triseriata</i> )	+		+
N. cricket frog ( <i>A. crepitans</i> )			+
River frog ( <i>R. heckscheri</i> )	+		X
Bog frog ( <i>R. okaloosae</i> )			X

X = principal or exclusive breeding habitat

+ = breeding habitats utilized

\* = typical frog components of upland habitats



## LITERATURE CITED

- Barlocher, F., R. J. Mackay and G. B. Wiggins. 1978. Detritus processing in a temporary vernal pool in southern Ontario. *Archiv fuer Hydrobiologie* 81: 269-295.
- Blaustein, A. R., and D. B. Wake. 1990. Declining amphibian populations: A global phenomenon? *Trends in Ecology and Evolution* 5(7): 203-204.
- Borchelt, R. 1990. Frogs, toads, and other amphibians in distress. *National Research Council NewsReport* 40(4): 2-5.
- Brown, M. T., and E. M. Starnes. 1983. A wetlands study of Seminole County. Center for Wetlands, University of Florida, Technical Report 41.
- Burton, T. M. and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. *Copeia* 1975: 541-546.
- Caldwell, J. P. 1987. Demography and life history of two species of chorus frogs (Anura: Hylidae) in South Carolina. *Copeia* 1987: 114-127.
- Dodd, C. K. and B. G. Charest. 1988. The herpetological community of temporary ponds in north Florida sandhills: species composition, temporal use, and management implications. pages 87-97 in R. C. Szaro, K. E. Severson, and D. R. Patton, editors. *Management of amphibians, reptiles, and small mammals in North America*. General Technical Report RM-166, USDA Forest Service, Rocky Mtn. Station, Ft. Collins, Colorado, USA.
- Forman, R. T. T., and M. Godron. 1986. *Landscape Ecology*. John Wiley and Sons, New York, New York, USA.
- Gosz, J. R., R. T. Holmes, G. E. Likens and F. H. Bormann. 1978. The flow of energy in a forest ecosystem. *Scientific American* 238(3): 92-102.
- Laney, R. W. 1988. The elimination of isolated and limited-flow wetlands in North Carolina. Pages 243-253 in W. L. Lyke and T. J. Hoban, editors. *Proceedings of the Symposium on Coastal Water Resources*. American Water Resources Association, Minneapolis, Minnesota, USA.
- Lippert, E. E., and D. L. Jameson. 1964. Plant succession in temporary ponds at Willamette Valley, Oregon. *American Midland Naturalist* 71: 181-197.
- Mitsch, W. J., and J. G. Gosselink. 1986. *Wetlands*. Van Nostrand Reinhold, New York, New York, USA.
- Moler, P. E. and R. Franz. 1987. Wildlife values of small, isolated wetlands in the southeastern coastal plain. Pages 234-241 in R. R. Odum, K. A. Riddleberger, and J. C. Ozier, editors. *Proceedings of the Third Southeast Nongame and Endangered Wildlife Symposium*. Georgia Department of Natural Resources, Atlanta, Georgia, USA.
- Patrick, W. H., Jr., and R. A. Khalid. 1974. Phosphate release and sorption by soils and sediments: effect of aerobic and anaerobic conditions. *Science* 186: 53-55.
- Pechmann, J. H. K., D. E. Scott, J. W. Gibbons, and R. D. Semlitsch. 1988. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetland Ecology and Management* 1: 1-9.
- Reed, P. B., Jr. 1988. National list of plant species that occur in wetlands: national summary. U.S. Fish and Wildlife Service Biological Report 88(24).
- Vitt, L. J., J. P. Caldwell, H. M. Wilbur, and D. C. Smith. 1990. Amphibians as harbingers of decay. *BioScience* 40(6): 418.
- Wassersug, R. J. 1975. The adaptive significance of the tadpole stage with comments on the maintenance of complex life cycles in anurans. *American Zoologist* 15: 405-417.
- Weller, M. W. 1978. Wetland habitats. Pages 210-234 in P. E. Greeson, J. R. Clark, and J. E. Clark, editors. *Wetland functions and values: The state of our understanding*. American Water Resources Association, Minneapolis, Minnesota, USA.
- Wharton, C. H. 1978. *The natural environments of Georgia*. Georgia Department of Natural Resources, Atlanta, Georgia, USA.
- Wilbur, H. M. 1980. Complex life cycles. *Annual Review of Ecology and Systematics* 11: 67-93.

THE ROLE OF AQUATIC PLANTS  
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## Are Small, Isolated Wetlands Expendable?

RAYMOND D. SEMLITSCH AND J. RUSSELL BODIE

Division of Biological Sciences, University of Missouri, Columbia, MO 65211-7400, U.S.A.,  
email rays@biosci.mbp.missouri.edu

**Abstract:** *What is most evident in the recent debate concerning new wetland regulations drafted by the U.S. Army Corps of Engineers is that small, isolated wetlands will likely continue to be lost. The critical biological question is whether small wetlands are expendable, and the fundamental issue is the lack of biologically relevant data on the value of wetlands, especially so-called "isolated" wetlands of small size. We used data from a geographic information system for natural-depression wetlands on the southeastern Atlantic coastal plain (U.S.A.) to examine the frequency distribution of wetland sizes and their nearest-wetland distances. Our results indicate that the majority of natural wetlands are small and that these small wetlands are rich in amphibian species and serve as an important source of juvenile recruits. Analyses simulating the loss of small wetlands indicate a large increase in the nearest-wetland distance that could impede "rescue" effects at the metapopulation level. We argue that small wetlands are extremely valuable for maintaining biodiversity, that the loss of small wetlands will cause a direct reduction in the connectance among remaining species populations, and that both existing and recently proposed legislation are inadequate for maintaining the biodiversity of wetland flora and fauna. Small wetlands are not expendable if our goal is to maintain present levels of species biodiversity. At the very least, based on these data, regulations should protect wetlands as small as 0.2 ha until additional data are available to compare diversity directly across a range of wetland sizes. Furthermore, we strongly advocate that wetland legislation focus not only on size but also on local and regional wetland distribution in order to protect ecological connectance and the source-sink dynamics of species populations.*

Son los Humedales Pequeños Prescindibles?

**Resumen:** *Algo muy evidente en el reciente debate sobre las nuevas regulaciones de humedales elaboradas por el cuerpo de ingenieros de la armada de los Estados Unidos es que los humedales aislados pequeños seguramente se continuarán perdiendo. La pregunta biológica crítica es si los humedales pequeños son prescindibles y e asunto fundamental es la falta de datos biológicos relevantes sobre el valor de los humedales, especialmente los llamados humedales "aislados" de tamaño pequeño. Utilizamos datos de GIS para humedales de depresiones naturales en la planicie del sureste de la costa Atlántica (U.S.A.) para examinar la distribución de frecuencias de los tamaños de humedales y las distancias a los humedales mas cercanos. Nuestros resultados indican que la mayoría de los humedales naturales son pequeños y que estos humedales pequeños son ricos en especies de anfibios y sirven como una fuente importante de reclutas juveniles. Análisis simulando la pérdida de humedales pequeños indican un gran incremento en la distancia al humedal mas cercano lo cual impediría efectos de "rescate" a nivel de metapoblación. Argumentamos que los humedales pequeños son extremadamente valiosos para el mantenimiento de la biodiversidad, que la pérdida de humedales pequeños causará una reducción directa en la conexión entre poblaciones de especies remanentes y que tanto la legislación propuesta como la existente son inadecuadas para mantener la biodiversidad de la flora y fauna de los humedales. Si nuestra meta es mantener los niveles actuales de biodiversidad de especies, los humedales pequeños no son prescindibles. En base en estos datos, las regulaciones deberían por lo menos proteger humedales tan pequeños como 0.2 ha hasta que se tengan a la mano datos adicionales para com-*

*parar directamente la diversidad a lo largo de un rango de humedales de diferentes tamaños. Mas aún, abogamos fuertemente por que la regulación de los pantanos se enfoque no solo en el tamaño, sino también en la distribución local y regional de los humedales para poder proteger la conexión ecológica y las dinámicas fuente y sumidero de poblaciones de especies.*

## Wetlands Debate

New regulations drafted by the U.S. Army Corps of Engineers that reduce protection for "headwater" or "isolated" wetlands have sparked a controversy among environmentalists, academic scientists, other federal agencies, and the Army Corps itself (Kaiser 1998). What is most evident in this debate is that small, isolated wetlands will likely continue to be lost no matter what the outcome. Why is there a bias against protecting small, isolated wetlands? The critical biological question is whether small wetlands are expendable, and the fundamental issue is the lack of biologically relevant data on the value of wetlands, especially so-called "isolated" wetlands of small size. Although the recently proposed legislation (U.S. Army Corps of Engineers, draft proposal) actually reduces the threshold size for developing wetlands from 4.0 ha to 1.2 ha (via Nationwide Permit 26), we believe that both the current and proposed legislation are inadequate for maintaining the biodiversity of wetland flora and fauna. We argue that small wetlands are extremely valuable for maintaining biodiversity in a number of plant, invertebrate, and vertebrate taxa (e.g., amphibians) and that the disappearance of small wetlands will cause a dire reduction in the ecological connectance among remaining species populations.

## Frequency and Distribution of Small Wetlands

Determining the frequency distribution of wetland sizes more appropriately addresses the biological importance of individual wetlands than approaches concerned only with how the total area would be affected by the loss of large versus small wetlands. Simple calculations show that a greater reduction in total wetland area obviously results from the loss of large wetlands. These calculations are often used to illustrate the importance of large wetlands, despite the absence of relevant biological data, and contribute to the bias against the value of small wetlands. Area is not the only important factor. We argue that the number of individual wetlands is more important because it addresses the abundance and distribution of individual wetland populations, which is the most basic unit of community dynamics responsible for maintaining species diversity (Ricklefs & Schluter 1993) and the most basic unit of population dynamics responsible for maintaining genetic diversity (Futuyma 1998). Therefore, the abundance of wet-

lands is directly related to critical processes of ecological change, such as connectance and source-sink dynamics, and of evolutionary change, such as genetic structure and local adaptation.

To examine the question of natural wetland abundance, we used as an example isolated depression wetlands distributed on the southeastern Atlantic coastal plain (U.S.A.). Existing geographic information system data from the 780-km<sup>2</sup> Savannah River Site (SRS) in South Carolina (Schalles et al. 1989; Kirkman et al. 1996) were used to describe the size frequency and spatial distribution of all detectable depression wetlands known as Carolina bays at this site. Carolina bays are natural elliptical depressions found in the southeastern United States that vary in size and geological age (Sharitz & Gibbons 1982). The 371 wetlands ranged in size from 0.22 (lower detection limit) to 78.2 ha, occurring at a density of 0.476/km<sup>2</sup>. The frequency distribution was highly skewed, with many more small than large bays (Fig. 1). In fact, 46.4% of the bays were 1.2 ha or less, and 87.3% were 4.0 ha or less. What is more, data for the frequency of small wetlands are conservative because bays smaller than 0.2 ha were not represented due to detection limits and may be common and quite important for some amphibian species.

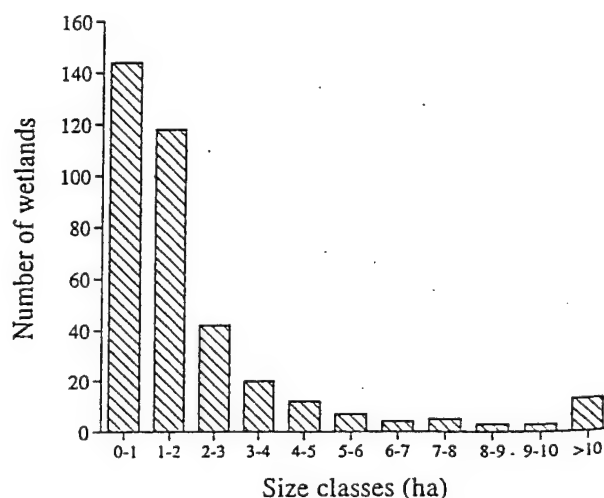


Figure 1. Distribution of natural depression wetland sizes ( $n = 371$ ) from the Savannah River Site on the upper coastal plain of South Carolina. The lower limit of detection from geographic information system data was 0.2 ha.

Of course, we should also question whether this data set is representative of other regions of the country. We have no reason to believe that the data are not representative of the entire southeastern United States, especially other undisturbed areas that have not already suffered a great loss of natural wetlands. Our results may also be comparable to regions other than the southeastern United States; for example, an analysis of wetlands in Maine revealed a slightly higher density ( $0.59/\text{km}^2$ ) but a similar high proportion of small wetlands (62% smaller than 4.05 ha; Gibbs 1993). Data from other regions, however, are needed to corroborate this general pattern that a majority of natural wetlands are small.

### Biodiversity of Small Wetlands

From an ecological perspective, small wetlands are crucial for maintaining regional biodiversity. For example, in a long-term study at a 0.5-ha Carolina bay on the SRS (Semlitsch et al. 1996), we observed one of the highest species diversities known for amphibians. We used amphibians as our model because they may constitute the greatest biomass among vertebrates in some ecosystems (Burton & Likens 1975) and are of global concern due to reported declines (Wake & Morowitz 1991; Blaustein et al. 1994) and extinctions (Pounds & Crump 1994). Furthermore, there is a wealth of information concerning community regulation and metapopulation dynamics for wetland amphibians (e.g., Gill 1978; Morin 1983; Smith 1983; Wilbur 1987; Berven & Grudzien 1990).

A 16-year monitoring study at a small wetland (0.5 ha) known as Rainbow Bay has documented 27 species of anurans and caudates (Semlitsch et al. 1996). In addition, the study also recorded the breeding activity of 41,776 females and the production of 216,251 metamorphosing juveniles during the 16-year period (Table 1 in Semlitsch et al. 1996). Monitoring studies of other small wetlands for shorter periods of time on the SRS have yielded similar numbers of amphibian species: Sun Bay (0.5 ha), 22 species (Gibbons & Semlitsch 1981); Karen's Pond (0.08 ha), 19 species; Risher Pond (1.1 ha), 18 species (Gibbons & Bennett 1974); Ginger's Bay (1.0 ha), 20 species; Quirrel Bay (0.5 ha), 21 species (D. Scott, personal communication). These data suggest that the levels of species richness found at Rainbow Bay are not uncommon and are representative of the region. Furthermore, studies of small, temporary wetlands in Florida (16 species of anurans and caudates at a 0.16-ha pond; Dodd 1992; Dodd & Cade 1998), Tennessee (19 species of anurans and caudates over 9 years at two small ponds each smaller than 0.2 ha; Scott & Bufalino 1997), and Texas (15 species of anurans alone; Wiest 1982) have yielded comparable numbers of species. Although we currently know of no study that statistically compares amphibian diversity in small and large isolated wetlands—a particularly impor-

tant comparison—some available data from Florida suggest that large wetlands may be less diverse (Moler & Franz 1987). Large wetlands tend to be more permanent and thus contain predatory fish and perhaps a greater variety or abundance of invertebrate predators that can exclude amphibian larvae (Morin 1983; Wilbur 1987; Semlitsch et al. 1996).

Our example demonstrates that small wetlands may be of significant biological importance, especially in producing large numbers of metamorphosing juvenile amphibians and potentially in maintaining the diversity of the regional amphibian fauna. We further suggest that such wetlands also are of general importance because they harbor large numbers of species of other taxa that are perhaps less mobile than birds or mammals and are therefore more strongly affected by the loss of small wetlands: wetland plants such as sundews (*Drosera* spp.) and pitcher plants (*Sarracenia flava*, *S. purpurea*; Sharitz & Gibbons 1982), microcrustaceans (Mahoney et al. 1989), and aquatic insects (Kondratieff & Pyott 1987; Sharitz & Gibbons 1982; Gaddy 1994).

### Consequences for Metapopulation Dynamics

The less obvious consequence of losing small, isolated wetlands lies in potential changes to the metapopulation dynamics of the remaining wetlands. There are two primary effects to consider (Gibbs 1993): (1) a reduction in the number or density of individuals dispersing and (2) an increase in dispersal distances among wetlands. The loss or alteration of any wetland, large or small, reduces the total number of sites at which pond-breeding amphibians can reproduce and successfully recruit juveniles into the breeding population. For amphibians the loss of small wetlands especially may reduce the number of source populations because juvenile recruitment is related to an optimal wetland size and intermediate hydroperiod that favor the periodic drying characteristic of small wetlands (Pechmann et al. 1989). Even at the best sites, however, reproductive failure in many years for nearly all species increases the probability of extinction (estimated annual reproductive failure rates are 42–56% for 13 species over 16 years in South Carolina; Semlitsch et al. 1996). Thus, the loss of small wetlands could be detrimental to rescue effects via a reduction in the population density and number of dispersing juveniles (contra Gibbs 1993). Even if recruitment failures proved to be less severe in other geographic regions, the change in wetland density over a local area would still become critical for other metapopulation processes. The effects of reduced wetland density also are manifested by an increase in the distance between neighboring wetlands and are critical to source-sink processes. In particular, a reduction in wetland density can decrease the probability that a population can be "rescued" from extinction by a neighboring source popu-

lation because of lower numbers of available recruits and greater distances between wetlands (Brown & Kodric-Brown 1977; Gill 1978; Pulliam 1988; Gibbs 1993).

To illustrate this point, we again use the example from the 371 Carolina bays on the SRS in South Carolina. We examined how the loss of individual wetlands affects the straight-line distance to the nearest wetland. The average distance to the nearest wetland directly affects the probability of migration and recolonization and, consequently, the chance of population rescue from extinction. It is also important to note that many pond-breeding salamanders, and possibly many anurans, are philopatric to natal ponds and do not emigrate long distances (most less than 200 m; Semlitsch 1998). In fact, an estimate of genetic-neighborhood size for wood frogs averages only 1126 m, suggesting that migration and gene flow are near zero at these distances (Berven & Grudzien 1990). From our example, we can see that the loss of small wetlands would dramatically increase the nearest-wetland distance from the initial 471 m (including all 371 wetlands) to 666 m with the loss of all wetlands smaller than 1.2 ha (proposed protection threshold) to 1633 m with the loss of all wetlands smaller than 4.0 ha (current protection threshold) (Fig. 2). What is most pertinent to current and proposed wetland-size legislation is that there would be a 41.3% increase (+195 m) in distance between nearest bays with the loss of all wetlands smaller than 1.2 ha and a 136.1% increase (+641 m) in distance with the loss of all wetlands smaller than 4.0 ha. We conclude from our analysis

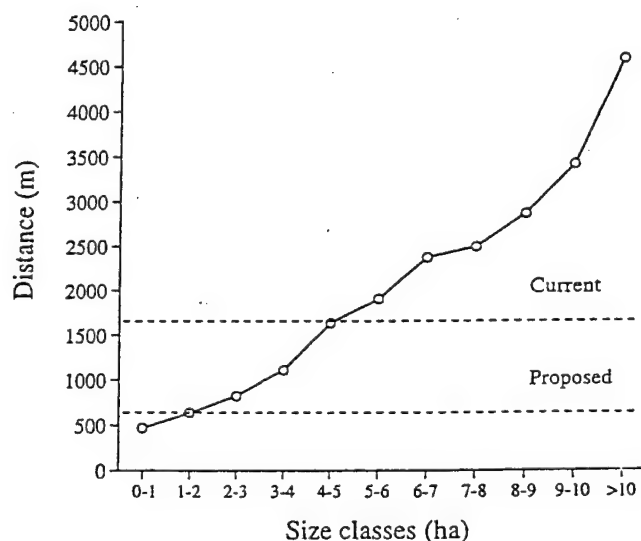


Figure 2. Mean distances between nearest wetlands ( $n = 371$ ) on the Savannah River Site on the upper coastal plain of South Carolina. The mean nearest-neighbor distance was recalculated sequentially with all previous wetland size classes removed. Dashed lines indicate current and proposed U.S. Army Corps of Engineers wetland size legislation thresholds.

that the loss of a majority of small wetlands could severely impede source-sink processes and place remaining wetlands at increased probabilities of population extinction (also see Gibbs 1993; Travis 1994).

## Implications for Management and Legislation

Small, isolated wetlands are not expendable if our goal is to maintain present levels of species biodiversity. We have shown that current and proposed legislation is inadequate for maintaining regional wetland biodiversity in at least one important group of vertebrates, amphibians. This is especially disheartening in light of the many reports of declining amphibian populations worldwide, and in particular because of habitat loss in the southeastern United States (Dodd 1997). We further suggest that such legislation is inadequate for other taxa, such as plants, microcrustaceans, and insects, that use small wetlands. At the very least, based on these data, regulations should protect wetlands as small as 0.2 ha until additional data are available to compare diversity directly across a range of wetland sizes. Furthermore, in order to protect the ecological connectance and source-sink dynamics of species populations, we strongly advocate that wetland legislation focus not only on size but also on local and regional wetland distribution. For instance, a 1.0-ha wetland isolated by 1000 m may have more rather than less biologic value than a 1.0-ha wetland with neighboring wetland 100–200 m away.

Only through analyses similar to those we have presented can a realistic view of the biological consequences of wetland legislation be understood. We hope our comments stimulate new efforts into research that includes analyses of how biodiversity relates to wetland size and spatial distribution and how metapopulation processes are affected by the loss of wetlands, both large and small.

## Acknowledgments

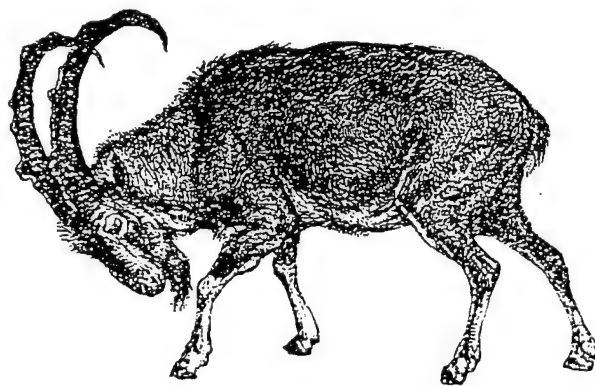
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## Literature Cited

- Berven, K. A., and T. A. Grudzien. 1990. Dispersal in the wood frog (*Rana sylvatica*): implications for genetic population structure. *Evolution* 44:2047–2056.



- Blaustein, A. R., D. B. Wake, and W. P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology* 8:60-71.
- J. H., and A. Kodric-Brown. 1977. Turnover rates in insular biogeography: effect of immigration on extinction. *Ecology* 58:445-449.
- Burton, T. M., and G. E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. *Copeia* 1975:541-546.
- Dodd, C. K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. *Biodiversity and Conservation* 1:125-142.
- Dodd, C. K., Jr. 1997. Imperiled amphibians: a historical perspective. Pages 165-200 in G. W. Benz and D. E. Collins, editors. *Aquatic fauna in peril: the southeastern perspective*. Special publication 1. Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, Georgia.
- Dodd, C. K., Jr., and B. S. Cade. 1998. Movement patterns and the conservation of breeding amphibians in small, temporary wetlands. *Conservation Biology* 12:331-339.
- Futuyma, D. J. 1998. *Evolutionary biology*. 3rd edition. Sinauer Associates, Sunderland, Massachusetts.
- Gaddy, L. L. 1994. The ecology of seven rare wetland species in Carolina bays and bay-like depressions in the western Coastal Plain of South Carolina. Report. U.S. Forest Service, Savannah River Forest Station, Aiken, South Carolina.
- Gibbons, J. W., and D. H. Bennett. 1974. Determination of anuran terrestrial activity patterns by a drift fence method. *Copeia* 1974:236-243.
- Gibbons, J. W., and R. D. Semlitsch. 1981. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. *Brimleyana* 7:1-16.
- Gibbs, J. P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. *Wetlands* 13:25-31.
- Gibbs, J. P., and E. 1978. The metapopulation ecology of the red-spotted newt, *Ambystoma viridescens* (Rafinesque). *Ecological Monograph* 48:145-166.
- Kaiser, J. 1998. New wetlands proposal draws flak. *Science* 279:980.
- Kirkman, L. K., R. F. Lide, G. Wein, and R. R. Sharitz. 1996. Vegetation changes and land-use legacies of depression wetlands of the western coastal plain of South Carolina: 1951-1992. *Wetlands* 16:564-576.
- Kondratieff, B. C., and C. J. Pyott. 1987. The anisoptera of the Savannah River Plant South Carolina U.S.A. thirty years later. *Odonatologica* 16:9-24.
- Mahoney, D. L., D. A. Mort, and B. E. Taylor. 1989. Species richness of calanoid copepods, cladocerans, and other branchiopods in Carolina bay temporary ponds. *American Midland Naturalist* 123:244-258.
- Moler, P. E., and R. Franz. 1987. Wildlife values of small, isolated wetlands in the southeastern coastal plain. Pages 234-241 in R. R. Odum, K. A. Riddleberger, and J. C. Ozier, editors. *Proceedings of the third southeastern nongame and endangered wildlife symposium*. Georgia Department of Natural Resources, Atlanta.
- Morin, P. J. 1983. Predation, competition, and the composition of larval anuran guilds. *Ecological Monograph* 53:119-138.
- Pechmann, J. H. K., D. E. Scott, J. W. Gibbons, and R. D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetlands Ecology and Management* 1:3-11.
- Pounds, J. A., and M. L. Crump. 1994. Amphibian declines and climate disturbance: the case of the golden toad and harlequin frog. *Conservation Biology* 8:72-85.
- Pulliam, H. R. 1988. Sources, sinks, and population regulation. *American Naturalist* 132:652-661.
- Ricklefs, R. E., and D. Schluter. 1993. *Species diversity in ecological communities: historical and geographical perspectives*. University of Chicago Press, Chicago, IL.
- Schalles, J. F., R. R. Sharitz, J. W. Gibbons, G. J. Leversee, and J. N. Knox. 1989. Carolina bays of the Savannah River Plant. Savannah River Plant National Environmental Research Park Program, Aiken, South Carolina.
- Scott, A. F., and A. Bufalino. 1997. Dynamics of the amphibian communities at two small ponds in Land Between the Lakes over the past decade. Page 117 in A. F. Scott, S. W. Hamilton, E. W. Chester, and D. S. White, editors. *Proceedings of the seventh symposium on the natural history of Lower Tennessee and Cumberland River valleys*. Austin Peay State University, Clarksville, Tennessee.
- Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12:1113-1119.
- Semlitsch, R. D., D. E. Scott, J. H. K. Pechmann, and J. W. Gibbons. 1996. Structure and dynamics of an amphibian community: evidence from a 16-year study of a natural pond. Pages 217-248 in M. L. Cody and J. A. Smallwood, editors. *Long-term studies of vertebrate communities*. Academic Press, San Diego, California.
- Sharitz, R. R., and J. W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. FWS/OBS-82/04. U.S. Fish and Wildlife Service, Washington, D. C.
- Smith, D. C. 1983. Factors controlling tadpole populations of the chorus frog (*Pseudacris triseriata*) on Isle Royale, Michigan. *Ecology* 64:501-510.
- Travis, J. 1994. Calibrating our expectations in studying amphibian declines. *Herpetologica* 50:104-108.
- Wake, D. B., and H. J. Morowitz. 1991. Declining amphibian populations: a global phenomenon? *Alytes* 9:33-42.
- Wiest, J. A., Jr. 1982. Anuran succession at temporary ponds in a post oak-savanna region of Texas. Pages 39-47 in N. J. Scott, Jr., editor. *Herpetological communities*. U.S. Fish and Wildlife Service, Washington, D.C.
- Wilbur, H. M. 1987. Regulation of structure in complex systems: experimental temporary pond communities. *Ecology* 68:1437-1452.





## Wildlife Values of Small, Isolated Wetlands in the Southeastern Coastal Plain

Paul E. Moler

Florida Game and Fresh Water Fish Commission  
4005 South Main Street  
Gainesville, Florida 32601

Richard Franz

Florida State Museum  
University of Florida  
Gainesville, Florida 32611

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### Abstract

Small, isolated wetlands are biologically unique systems, supporting a diverse assemblage of species quite different from that found in larger, more permanent bodies of water. At least 10 species of anurans and 5 species of salamanders of the southeastern Coastal Plain are exclusively or primarily dependent on small, isolated wetlands as breeding sites. Additionally, such sites provide important foraging and nesting habitat for a variety of wading birds.

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### Introduction

In recent years, considerable emphasis has been placed on wetlands protection, but the principal focus has been on larger wetland systems. To a great extent, the unique values and functions of small, isolated wetlands have been overlooked. This oversight derives from several factors, perhaps foremost being the general tendency to think of small wetlands as being little more than subsets of larger wetlands. So long as the uniqueness of small wetlands is unrecognized, then it is intuitive to think of wetlands as declining in value directly as a function of size. Similarly, so long as the unique values of isolated wetlands are unrecognized, it is understandable that connected wetlands might be considered of greater value.

In reality, small isolated wetlands are biologically unique systems. Because of their isolation and small size, they support a very different assemblage of species than that found in larger, more permanently wet situations. The ephemeral nature of many small wetlands makes them unsuitable for species which require permanent water. Many amphibians, though, because they require aquatic habitats for only a portion of their life history, are able to exploit the seasonally rich resource provided by ephemeral wetlands. Still other species (crayfish and some aquatic salamanders) escape desiccation by burrowing into the bottom and remaining there until rains again fill the pond.

Our discussion focuses on the importance of small, isolated wetlands to amphibians and wading birds. Much of the information which we will present is derived from our own experience and that of others in Florida, but it is applicable to other areas of the southeastern Coastal Plain as well. In particular, many of the members of the Floridan assemblage of amphibian species discussed here occur northward to southeastern Virginia and westward to the Florida parishes of Louisiana (Conant 1975).

### Materials and Methods

Field work reported here was conducted by 1 of us (RF) on the Katharine Ordway Preserve-Swisher Memorial Sanctuary, a 3750 ha nature preserve and research facility of the University of Florida located 3 km east of Melrose, Putnam County, Florida. Wetland habitats comprise 34% of the Preserve, with the remainder consisting of xeric hammock and sandhills. Established as a preserve in 1980, the property had been a private fishing retreat of the Swisher family since 1927.

Weekly surveys were conducted for calling frogs from March 1983 to February 1985 and sporadically thereafter. Fish surveys were conducted by seine, hand dredge and trotline from January 1985 to present. A total of 41 bodies of water were included in the surveys, comprised of 25 isolated (independent basins) lakes and ponds and 16 lakes and ponds associated with Mill Creek (Etoniah-Rice Creek system) or within its 100-year flood plain. Isolated systems included 6 sandhill lakes, 9 permanent sandhill ponds and 10 temporary sandhill ponds. Connected wetlands included 7 permanent lakes, 3 semi-permanent ponds and 6 temporary ponds.

### Results

A total of 16 native species of anurans was recorded breeding on the Ordway Preserve (Table 1). Fourteen species were recorded in isolated wetlands and 11 species in connected wetlands. Of the 11 species using connected wetlands, 2 (*Limnaeodius ocularis* and *Gastrophryne carolinensis*) were recorded only as rare occurrences in temporary ponds; both of these species were common in isolated wetlands. Similarly, of the 14 species using isolated wetlands, 1 (*Hyla cinerea*) occurred there only rarely, but it was common in connected wetlands. Two species (*Rana heckscheri*

and *R. clamitans*) were recorded only in connected wetlands, whereas 5 species (*H. gratiosa*, *Bufo quercicus*, *Scaphiopus holbrookii*, *R. areolata* and *R. castesbeiana*) were recorded only in isolated wetland systems.

Table 2 presents the relative distribution of fish and breeding anurans within the 6 wetland types examined. Not surprisingly, the greatest number of fish species was found in permanent lakes of the Mill Creek system. The greatest number of breeding anurans was to be found in isolated ephemeral ponds.

Salamanders of the genus *Ambystoma*, many of which are obligate ephemeral pond breeders, are not known on the Ordway Preserve. However, *Notophthalmus perstriatus*, another small pond breeding salamander, was collected from 6 sites, each of which was no larger than 0.2 ha.

## Discussion

### Amphibians

Because of their characteristic vocalizations, frogs are the most conspicuous vertebrate components of small wetland habitats. At least 29 native species of anurans occur in the southeastern Coastal Plain (Conant 1975) (Table 3). Ten of these breed primarily or exclusively in small, isolated, often ephemeral wetlands, and at least 10 others utilize such habitats opportunistically. The bullfrog group of eastern North American *Rana* (*R. castesbeiana*, *R. gryllo*, *R. heckscheri*, *R. clamitans*, *R. virgatipes*, *R. okaloosae*) (Moler 1985) typically spend their first year as aquatic larvae and are, thus, unsuited for reproduction in ephemeral wetlands. Nonetheless, most do breed in the more permanent isolated wetlands. The rarity of *H. crucifer* and the absence of *R. clamitans* in the isolated wetlands of the Ordway Preserve reflect the inhospitable xeric uplands surrounding most of the isolated wetlands there. Both species are usually associated with forested wetlands; they are known to breed in ephemeral wetlands elsewhere (Martof 1952, Pechmann et al. in press, pers. obs.).

Extensive, permanent, freshwater marshes are widespread in the lower Coastal Plain, yet only 4 species of anurans (*R. utricularia*, *R. gryllo*, *H. cinerea* and *Acris gryllus*) breed in numbers in such habitats, with 1 other (*B. terrestris*) breeding along the margins. Often, those species which are able to reproduce in larger, permanent wetland habitats are characterized by unpalatable or toxic eggs or tadpoles (Voris and Bacon 1966; Licht 1968, 1969; Wassersug 1975; Kruse and Francis 1977; Morin 1983), have eggs which are physically more resistant to predation (Grubb 1972), or display behavioral or phenotypic patterns which reduce vulnerability to predation (Caldwell et al. 1980, Caldwell 1982). It is important to recognize that, for many species of anurans, the use of small isolated

wetlands is obligative. Their eggs and larvae are simply not adapted to withstand the levels of predation encountered in more permanent wetlands (Heyer et al. 1975; Wilbur 1980; Woodward 1983; Morin 1983). In the survey of anuran breeding sites on the Ordway Preserve, small, isolated, temporary wetlands were the single most important habitat, both in terms of total number of species and average number of species per site.

Caldwell (1987) reported a 4 year study of 2 species of chorus frogs, both ephemeral pond breeders. The 1 ha pond under study normally dried during the fall dry season and was refilled by winter rains. The second year of her study was characterized by an unusually wet fall, such that the pond did not dry but rather was continuously wet from September through the following May. No ornate chorus frogs (*Pseudacris ornata*) and few southern chorus frogs (*P. nigrita*) bred there that year. In the 3 years in which the pond dried in the fall and then refilled, the pond was used by a breeding population of 199-249 ornate chorus frogs. Pechmann et al. (1987) similarly reported that *G. carolinensis* and *H. femoralis* were able to successfully reproduce only after a site dried and then refilled for several weeks during their breeding season. It appears that no single parameter is as important as ephemerality in governing successful reproduction by some species of amphibians.

In addition to anurans, 5 species of southeastern salamanders breed more or less exclusively in small, isolated wetland habitats free of predatory fish, and at least 7 other species use these habitats as well as more permanent sites (Table 4). These species or their larvae are often major predators on tadpoles, and several studies have shown that the density of predatory salamanders can drastically alter the composition of larval anuran communities (Caldwell et al. 1980; Morin 1981, 1983; Wilbur et al. 1983). Of the 5 species of obligate ephemeral wetland breeding salamanders shown in Table 4, only 1, the striped newt (*N. perstriatus*), is found on the Ordway Preserve. As are several of the frogs, striped newts are apparently totally dependent upon small, isolated wetlands. The species is known to breed in only 6 Ordway ponds, each of which is smaller than 0.2 ha.

The numbers of individual amphibians using even very small wetlands can be quite large. Goin (1938) reported capturing 130 male and 40 female *H. gratiosa* from a pond of 0.05 ha and estimated that he had captured about 90% of the frogs present. If we assume a 1:1 sex ratio to correct for females not at the pond when it was sampled and correct for the estimated 10% of frogs missed, Goin's data would suggest that this very small pond supported a breeding population of at least 288 *H. gratiosa*. Pechmann et al. (1987) provide data for production from a 1 ha ephemeral pond. In an especially good year, 75,644 juvenile

amphibians of 15 species metamorphosed from Rainbow Bay in Aiken County, South Carolina.

Amphibians are a cornerstone of the vertebrate food chain. In addition to the importance of larvae and aquatic forms as prey for wading birds, many terrestrial predators feed to varying degrees on amphibians. Wassersug (1975) commented, "The *amphibious* life cycle of anurans constitutes one of the few biotic mechanisms for transport of excessive nutrients out of eutrophic bodies of water and back into the terrestrial ecosystems."

The importance of small isolated wetlands to local energy cycles may extend far beyond their borders. Both *B. woodhousei* (Breden 1987) and *R. areolata* (pers. obs.) have been documented to disperse distances of at least 2 km from ponds where they were marked. Indigo snakes (*Drymarchon corais*), hognosed snakes (*Heterodon* spp.), garter snakes (*Thamnophis sirtalis*), ribbon snakes (*Thamnophis sauritus*), black racers (*Coluber constrictor*) and juvenile rat snakes (*Elaphe* spp.) feed heavily on frogs. Because small wetlands tend to be scattered widely over the landscape, they are an important source of prey for these and other predators; the loss of such wetlands can impact wildlife populations to a considerable distance away from the pond. If we use Breden's (1987) 2 km as the dispersal distance away from a pond, then the production would be scattered over a terrestrial habitat of some 1300 ha. (Actual dispersal distance would, of course, vary greatly between species.) Thus, the toads from a seemingly insignificant 1 ha pond might support a population of hognosed snakes occupying over 1000 ha of upland habitats.

Although we know of no comparable data for the southeastern United States, the work of Burton and Likens (1975) and Gosz et al. (1978) in New Hampshire is suggestive of the important role of amphibians in energy cycling. Burton and Likens (1975) found that the biomass of salamanders was about double that of birds during the peak bird breeding season and about equal to the biomass of small mammals. Gosz et al. (1978) found that salamanders and shrews were the most important vertebrates preying on the invertebrates of the forest floor. They estimated that birds consume 6.5 times and shrews 4.7 times the amount of food energy consumed by the salamander community. However, because the warm-blooded birds and shrews expend 98% of their energy intake on maintenance compared to only 40% for the salamanders, salamanders contribute 4.6 (shrews) to 6.3 (birds) times as much biomass to the available prey base. The diverse and abundant anuran community of the southeastern Coastal Plain no doubt plays an equally important role in vertebrate food chains.

## Birds

Small wetlands are important as both nesting and foraging habitats for a variety of birds. Walkinshaw (1981) observed 137 Florida sandhill crane (*Grus canadensis pratensis*) nests in central Florida and reported that 81

(59%) were located in ponds less than 4.1 ha in size. He further noted that during wet years the cranes appeared to nest in even smaller ponds.

Although colonial wading birds are not restricted in nesting habitat to isolated wetlands, small wetlands sometimes support impressive wading bird rookeries. We know of 1 rookery in Duval County, Florida, in which well over 1000 wading bird nests are supported by a pond of 1.6 ha and another in which several hundred nesting pairs use a pond of only 0.5 ha (B. Mansell, pers. commun.)

Because of their high productivity and fluctuating water levels, which result in seasonal concentration of prey organisms, isolated wetlands are important foraging areas for a variety of birds, especially wading birds. Kushlan (1979) reported that movements of white ibis (*Eudocimus albus*) in south Florida corresponded to the patterns of drying, and that ibis generally fed near the edge of drying pools.

Wood stork (*Mycteria americana*) reproduction is strongly dependent on receding dry season water levels, which concentrate prey organisms such that wood storks are able to acquire sufficient food to successfully rear their young (Ogden et al. 1976). Small isolated wetlands are especially important early in the nesting season because they are usually the first to dry, thus providing the critical food concentrations at the onset of nesting. However, wood storks require a progression of drying ponds throughout the nesting season and, thus, require numerous ponds of varying sizes and degrees of ephemerality.

The snail kite (*Rostrhamus sociabilis*) is usually associated with extensive marsh habitats. Beissinger and Takekawsa (1983) reported, though, that during the severe drought of 1981, snail kites dispersed widely throughout the southern Florida peninsula, frequently using small (2-5 ha) permanent and seasonal wetlands. They suggested that such areas "are important for kite survival during Florida's cyclic droughts and need to be preserved to insure survival during these periods."

## Regulatory Considerations

A recent Florida study (Brown and Starnes 1983) attempted to evaluate wetlands by several criteria, including size, connectedness, landscape diversity, quality of surrounding landscape, intactness, uniqueness, and utilization by endangered species. Germane to the discussion here, wetland value was suggested to decline directly as a function of size and isolation. To be sure, the values and functions of wetlands are diverse, and any attempt to evaluate wetlands will likely emphasize some values at the expense of others. But, for the moment, let us consider only wildlife values.

Size alone is not an adequate index of wildlife value of a wetland. Small wetlands support a diverse and unique biological community, quite different from that to be found in larger, permanent bodies of water. The values and functions of small wetlands are different

from those of larger wetlands, but small wetlands can not be assumed to be of lesser value.

The question of the importance of isolation versus connectedness in evaluating wetlands is complex. In terms of hydrological values, isolated wetlands serve as natural stormwater catchments. Also, as we have seen, isolated wetlands are of unique biological importance, and many species are totally dependent on them, in large part because of their isolation. Isolated wetlands, by virtue of their separation from larger wetland systems, contribute to local landscape diversity. Because they are scattered widely across the landscape, they provide an important local source of drinking water to many forms of terrestrial wildlife. In a very real sense, the wildlife value of a wetland increases directly as a function of its isolation.

Regulatory agencies sometimes refer to actions which "improve hydroperiod." There is seldom any indication of what constitutes "improvement," but the usual interpretation is to increase the hydroperiod. From the perspective of amphibian biology, the term "improve hydroperiod" is dangerously ill-defined. Clearly, if one wishes to manage for a particular species, the hydroperiod can be manipulated to maximize benefits to that species. In some cases this would involve prolonging inundation, but in others it would involve reducing the hydroperiod.

Wilbur (1980) pointed out that "(t)he limit on the permanent end of the continuum is probably set by the species' susceptibility to predation. The more nearly permanent a pond is, the greater the range of predators it supports and the greater the likelihood that it contains fish. Temporary ponds have a two-fold advantage for amphibians. The flush of primary productivity following flooding permits rapid growth and high population densities. The drying of the pond eliminates fish and other large predators so that when the pond fills tadpoles have an initial size advantage over invertebrate predators..."

The composition of the amphibian community surrounding a wetland is a reflection of both the upland habitats and the unique hydroperiod of the particular wetland. Alteration of the hydroperiod, whether by increasing or decreasing the period of inundation, may result in the drastic restructuring of that amphibian community.

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### Literature Cited

Beissinger, S.R. and J.E. Takekawa. 1983. Habitat use by and dispersal of snail kites in Florida during drought conditions. Fla. Field Nat. 11:89-106.

- Breden, F. 1987. The effect of post-metamorphic dispersal on the population genetic structure of Fowler's toad, *Bufo woodhousei fowleri*. Copeia 1987:386-395.
- Brown, M.T. and E.M. Starnes. 1983. A wetlands study of Seminole County. Center for Wetlands, University of Florida. Tech. Report 41.
- Burton, T.M. and G.E. Likens. 1975. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. Copeia 1975:541-546.
- Caldwell, J.P. 1982. Disruptive selection: a tail color polymorphism in *Acris* tadpoles in response to differential predation. Can. J. Zool. 60:2818-2827.
- \_\_\_\_\_. 1987. Demography and life history of two species of chorus frogs (Anura:Hylidae) in South Carolina. Copeia 1987: 114-127.
- \_\_\_\_\_, J.H. Thorp and T.O. Jervy. 1980. Predator-prey relationships among larval dragonflies, salamanders, and frogs. Oecologia 46:285-289.
- Conant, R. 1975. A field guide to reptiles and amphibians of eastern and central North America. 2nd ed. Houghton Mifflin Co., Boston.
- Goin, C.J. 1938. A large chorus of *Hyla gratiosa*. Copeia 1938:48.
- Gosz, J.R., R.T. Holmes, G.E. Likens and F.H. Bormann. 1978. The flow of energy in a forest ecosystem. Sci. Amer. 238(3):92-102.
- Grubb, J.C. 1972. Differential predation by *Gambusia affinis* on the eggs of seven species of anuran amphibians. Amer. Midl. Nat. 88:102-108.
- Heyer, W.R., R.W. McDiarmid and D.L. Wiegmann. 1975. Tadpoles, predation and pond habitats in the tropics. Biotropica 7(2):100-111.
- Kruse, K.C. and M.G. Francis. 1977. A predation deterrent in larvae of the bullfrog, *Rana catesbeiana*. Trans. Am. Fish. Soc. 106:248-252.
- Kushlan, J.A. 1979. Feeding ecology and prey selection in the white ibis. Condor 81:376-389.
- Licht, L.E. 1968. Unpalatability and toxicity of toad eggs. Herpetologica 24:93-98.
- \_\_\_\_\_. 1969. Palatability of *Rana* and *Hyla* eggs. Am. Midl. Nat. 82:296-298.
- Martof, B. 1952. Early transformation of the green frog, *Rana clamitans* Latreille. Copeia 1952:115-116.
- Moler, P.E. 1985. A new species of frog (Ranidae: *Rana*) from northwestern Florida. Copeia 1985:379-383.
- Morin, 1981. Predatory salamanders reverse the outcome of competition among three species of anuran tadpoles. Science 212:1284-1286.
- \_\_\_\_\_. 1983. Predation, competition, and the composition of larval anuran guilds. Ecol. Monogr. 53:119-138.
- Ogden, J.C., J.A. Kushlan and J.T. Tilment. 1976. Prey selectivity of the wood stork. Condor 78:324-330.
- Pechmann, J.H.K., D.E. Scott, J.W. Gibbons, and R.D. Semlitsch. 1987. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile

-amphibians. Wetlands Ecology and Management *in press*.

Voris, H.K. and J.P. Bacon, Jr. 1966. Differential predation on tadpoles. *Copeia* 1966:594-598.

Walkinshaw, L.H. 1981. Nesting of the Florida sandhill crane in central Florida. pp. 53-62 *in* J.C. Lewis, ed., Proc. 1981 Crane Workshop. Nat. Audubon Soc., Tavernier, Florida.

Wassersug, R.J. 1975. The adaptive significance of the tadpole stage with comments on the maintenance of complex life cycles in anurans. *Amer. Zool.* 15:405-417.

Wilbur, H.M. 1980. Complex life cycles. *Ann. Rev. Ecol. Syst.* 1980:67-93.

\_\_\_\_\_, P.J. Morin, and R.N. Harris. 1983. Salamander predation and the structure of experimental communities: anuran responses. *Ecology* 64:1423-1429.

Woodward, B.D. 1983. Predator prey interactions and breeding pond use of temporary-pond species in a desert anuran community. *Ecology* 64:1549-1555.



Table 1. Occurrence of breeding anurans on the Katharine Ordway Preserve—Swisher Memorial Sanctuary.  
(C=common; U=uncommon; R=rare)

	Isolated Wetlands	Connected
<i>Acris gryllus</i>	C	C
<i>Limnaeodius ocularis</i>	C	R (Temp.)
<i>Hyla femoralis</i>	C	R
<i>H. gratiosa</i>	C	-
<i>H. crucifer</i>	R	C
<i>H. cinerea</i>	R	C
<i>Gastrophryne carolinensis</i>	C-U	R (Temp.)
<i>Bufo terrestris</i>	U	U
<i>B. quercicus</i>	C	-
<i>Scaphiopus holbrookii</i>	C (Temp.)	-
<i>Rana areolata</i>	C (Temp.)	-
<i>R. utricularia</i>	C	U
<i>R. catesbeiana</i>	U	-
<i>R. gryllo</i>	U	C
<i>R. heckscheri</i>	-	C
<i>R. clamitans</i>	-	C
Total number species	14	11

Table 2. Recorded occurrence of fish and anurans in different wetland types on the Katharine Ordway Preserve—Swisher Memorial Sanctuary.

	n	size (ha)	$\bar{x}$ # fish species	# anuran species	
				$\bar{x}$	total
Darkwater (connected)					
Permanent lakes	7	8.6-77.8	12.6	5.4	10
Semi-permanent ponds	3	0.1-3.0	4.6	3.0	4
Temporary ponds	6	>0.1	0	3.4	8
Clearwater (isolated)					
Permanent lakes	6	5.7-58.7	5.7	3.6	6
Permanent ponds	9	>0.1-3.7	5.3	3.3	8
Temporary ponds	10	>0.1-0.3	0	6.4	13

Table 3. Principal breeding habitats utilized by frogs and toads of the southeastern Coastal Plain. (X=principal or exclusive breeding habitat; +=breeding habitats utilized).

Species	Small Isolated Wetlands	Open Marsh	Riparian & Forested Wetlands
Eastern spadefoot ( <i>Scaphiopus holbrookii</i> )	X		
Oak toad ( <i>Bufo quercicus</i> )	X		
Barking treefrog ( <i>Hyla gratiosa</i> )	X		
Squirrel treefrog ( <i>H. squirella</i> )	X		
Pinewoods treefrog ( <i>H. femoralis</i> )	X		
Little grass frog ( <i>Limnaeoedus ocularis</i> )	X		
Ornate chorus frog ( <i>Pseudacris ornata</i> )	X		
Southern chorus frog ( <i>P. nigrita</i> )	X		
Gopher frog ( <i>Rana areolata</i> )	X		
E. narrowmouth toad ( <i>Gastrophryne carolinensis</i> )	X	+	
Spring peeper ( <i>H. crucifer</i> )	+		+
Southern toad ( <i>B. terrestris</i> )	+	+	+
Green treefrog ( <i>H. cinerea</i> )	+	+	+
Gray treefrog ( <i>H. chrysoscelis</i> )	+		+
S. cricket frog ( <i>Acris gryllus</i> )	+	+	+
Bronze frog ( <i>R. clamitans</i> )	+		+
Pig frog ( <i>R. grylio</i> )	+	+	+
Bullfrog ( <i>R. catesbeiana</i> )	+		+
S. leopard frog ( <i>R. utricularia</i> )	+	+	+
Carpenter frog ( <i>R. virgatipes</i> )	+	+	+
Fowler's toad ( <i>B. woodhousei</i> )			+*
Bird-voiced treefrog ( <i>H. avivoca</i> )			+
Pine Barrens treefrog ( <i>H. andersonii</i> )			+
Upland chorus frog ( <i>P. triseriata</i> )	+		+*
Brimley's chorus frog ( <i>P. brimleyi</i> )			+
N. cricket frog ( <i>A. crepitans</i> )			+*
River frog ( <i>R. heckscheri</i> )	+		X
Pickerel frog ( <i>R. palustris</i> )			X
Bog frog ( <i>R. okaloosae</i> )			X

\*Species with very narrow ecological tolerances in Florida, but likely use other habitats elsewhere.



Table 4. Salamanders commonly using small, isolated wetland habitats in the southeastern Coastal Plain.

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Species restricted in breeding habitat to small, isolated wetlands:

Tiger salamander (*Ambystoma tigrinum*)  
Flatwoods salamander (*A. cingulatum*)  
Mabee's salamander (*A. mabeei*)  
Mole salamander (*A. talpoideum*)  
Striped newt (*Notophthalmus perstriatus*)

Species using small, isolated wetlands in addition to other habitats:

Spotted salamander (*A. maculatum*)  
Marbled salamander (*A. opacum*)  
Eastern newt (*N. viridescens*)  
Lesser siren (*Siren intermedia*)  
Dwarf siren (*Pseudobranchius striatus*)  
Two-toed amphiuma (*Amphiuma means*)  
Dwarf salamander (*Eurycea quadridigitata*)

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# VEGETATION OF SELECTED UPLAND TEMPORARY PONDS IN NORTH AND NORTH-CENTRAL FLORIDA

Linda V. LaClaire<sup>1</sup>

## ABSTRACT

Vegetation was sampled in 13 temporary ponds located in uplands of north and north-central Florida. The ponds were selected for study because they represented potential breeding sites for 2 rare amphibians, the gopher frog, *Rana capito aesopus*, and the striped newt, *Notophthalmus perstriatus*. Vegetation in the non-forested depression ponds was analyzed in order to determine if a set of characteristic species was present in each. These data then could be used to identify breeding sites for the two species and to provide information for use in the development of management plans for the sites. The study ponds generally fill during winter rains and completely dry down during the summer, but, during the period of this research, Florida was experiencing a relatively dry period, and some ponds did not fill on an annual basis.

A total of 112 vascular plant species were identified in the pond basins. *Panicum hemitomon* was the only species present at each pond. Other common species included *Andropogon glomeratus*, *Rhexia mariana* var. *mariana*, *Eupatorium leptophyllum*, *Rhynchospora* spp., *Ilex glabra*, *Cephalanthus occidentalis*, and members of the family Eriocaulaceae. Similarities between ponds generally resulted from similarities in hydrologic cycle, defined as the period of time since each had held water, and the proximity of ponds to each other. The vegetation of each pond reflected a pattern of zonation or banding commonly described for temporary ponds in other regions. Wetland index values calculated for each pond fit wetland designation criteria, including a basin that had not formed a pond for 7 years, Dry Pond. Species richness and diversity were highest in ponds that had recently dried down and lowest in flooded ponds and Dry Pond.

## RESUMEN

Se muestreó la vegetación de 13 estanques temporarios en las tierras altas del norte y norte-centro de Florida. Se seleccionaron los estanques que representaban potenciales sitios reproductivos de dos especies raras de anfibios, el sapo excavador de Florida, *Rana capito aesopus*, y la salamandra rayada, *Notophthalmus perstriatus*. Estos estanques, que ocupan bajos en áreas no forestadas, se ajustan a un patrón general de llenado durante las lluvias de invierno y de completo vaciamiento durante el verano. Florida

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<sup>1</sup> The author is a Wildlife Biologist of Herpetology and Avian Ecology at the U. S. Fish and Wildlife Service, 6578 Dogwood View Parkway, Suite A, Jackson MS 39213, USA.

experimentó un período relativamente seco durante este estudio y por lo tanto, algunos estanques no se llenaron anualmente.

Las comunidades vegetacionales se identificaron en base a información de transectos y búsquedas de circuitos en las cuencas de los estanques. Con el objeto de determinar sin un número de especies características pudiera ser utilizado para la identificación de sitios de reproducción de las dos especies de anfibios, se realizaron análisis vegetacionales. Se identificó un total de 112 plantas vasculares provenientes de cuencas en los estanques. *Panicum hemitomon* fue la única especie presente en cada estanque. Otras especies comunes fueron *Andropogon glomeratus*, *Rhexia mariana* var. *mariana*, *Eupatorium leptophyllum*, *Rhynchospora* spp., *Ilex glabra*, *Cephalanthus occidentalis* y miembros de la familia Eriocaulaceae. Las semejanzas vegetativas entre estanques, estuvieron por lo general correlacionadas con similitudes en el ciclo hidrológico (el tiempo transcurrido desde que cada estanque tuvo agua) y la cercanía entre estanques. La vegetación en cada estanque reflejó un patrón de zonación comúnmente descrito para estanques temporarios en otras regiones. Los valores de índices de humedales calculados para cada estanque cayeron dentro del rango descrito para humedales, incluyendo una cuenca que no formó estanque durante 7 años. La riqueza y diversidad de especies fueron máximas en estanques secados recientemente (< 1 año desde inundación) y mínimas en estanques inundados y en estanques secos por varios años.

## INTRODUCTION

Vegetation data from upland temporary ponds in north and north-central Florida were collected as part of a larger project to determine the ecology and distribution of two rare amphibians, the Florida gopher frog, *Rana capito aesopus*, and the striped newt, *Notophthalmus perstriatus* (LaClaire 1992; Franz and Smith 1993). Temporary ponds are required breeding habitat for these upland-dwelling amphibians (Moler and Franz 1987). In order to ensure the survival of these two species, effective management of their breeding habitat is imperative.

An understanding of the temporary pond plant community is essential to the development of appropriate management plans for these pond basins. The wetland vegetation of temporary ponds is an important source of available nutrients for pond-dwelling plants and animals and of humified organic matter that may be crucial to the ability of a pond to hold water (LaClaire 1992).

It is especially important that management practices do not alter the existing hydrology of a temporary pond basin. Alteration of the hydrologic regime may seriously impact the development of hydric soils, structure of the plant community, and temporal use by amphibians. Both reduction of the water budget and stabilization of water levels have figured prominently in the ecological decline of many undrained Florida wetlands (Lowe 1986). For example, use of temporary ponds as water retention basins stabilizes the water level and may result in successional changes toward a community dominated by emergent genera such as *Pontederia* sp., *Typha* sp., or *Scirpus* sp., rather than the grass/sedge community (Botts and Cowell 1988) required by many species of amphibians for egg attachment. The high variability and instability of the hydrologic component of the temporary pond environment results in a community which is highly susceptible to other disturbance (Gopal 1986).

The objective of this study was to provide information on the vegetative community of upland temporary ponds in north and north-central Florida. Little information is available on the species composition and distribution in these wetlands. Plant community structure was investigated with the goal of formulating some generalizations about the pond habitat which could be used to identify the type temporary pond used for breeding by the gopher frog and/or the striped newt. To fulfill the study objective the following questions were asked:

- 1) What plant species characterize each pond basin?
- 2) How similar is the vegetation of each site to each other?
- 3) Does the vegetation reflect a pattern of structure, association, spatial shift, or zonation?
- 4) Since considerable attention has been focused on wetland designation criteria, does the vegetation of each pond correspond to a wetland index value indicative of wetland?
- 5) What is the effect of hydrology on species richness, diversity, and distribution?

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## TEMPORARY PONDS

### Defining a Temporary Pond

Temporary wetlands can be defined as natural bodies of water which experience a recurrent dry phase of varying duration (Williams 1987). The hydrologic emphasis in these wetlands is on the cyclic nature of drying and re-filling as permanent waterbodies are also capable of drying completely in exceptional years. In addition, selection has occurred in temporary wetlands for species adapted to this cyclic drying and filling and results in periodic bursts of productivity that fuel these systems (Patrick and Khalid 1974; Brinson et al. 1981; Reddy and Graetz 1988).

A temporary pond is a small (generally less than 5 hectares), isolated, temporary wetland that is depressional in nature. There is considerable confusion of terms in dealing with these small temporary wetlands, both among regulatory agencies and in the literature. Terms used to describe them include flatwoods marshes/ponds, ephemeral ponds/wetlands, highlands marshes, pineland depressions, depression meadows/marshes, St. John's wort ponds, seasonal marshes/ponds, intermittent ponds, and vernal pools (Holland 1988; Florida Natural Areas Inventory and Florida Department of Natural Resources 1990; Kushlan 1990). Some of these terms allude to the fact that temporary ponds are difficult to identify as wetlands during their dry cycle (Means 1990).

### Hydrology

Hydrology is the major factor influencing and maintaining the community of wetland plants in the temporary pond basin (Mitsch and Gosselink 1986). External water inputs transport nutrients into the system and mobilize those bound in vegetation and soil. Water depth, duration, and frequency of flooding all influence the formation of hydric soils and the presence of hydrophytes within the pond (Gosselink and Turner 1978). The hydroperiod of temporary ponds is highly variable, depending upon elevation, basin characteristics, and rainfall patterns (Means 1990). Some ponds may fill and dry on an annual basis while others may contain water only in the wettest years.

When a temporary pond drains, productivity is lowered and aerobic decomposers begin rapidly breaking down the accumulated organic matter (Cole and Fisher 1979; Reddy et al. 1986). Temporary ponds are detrital systems, and most of the organic production decomposes before entering the detrital food chain (Mitsch and Gosselink 1986). The vegetation of the pond basin is readily and almost completely decomposed on a cyclic basis (Gopal 1986). The breakdown of

organic matter facilitates maintenance of a temporary pond rather than a permanent one.

### **Life History Strategies of Wetland Plants**

Three key life history traits can be used to characterize wetland species (van der Valk 1981). These are life span, propagule longevity, and propagule establishment requirements. Propagules may be seeds or vegetative structures, and a single species may have both modes of reproduction which function under different hydrologic regimes.

Wetland plants include both annuals and perennials. Annuals may be found on exposed soil during drawdowns or may occur as submersed or free-floating aquatics (van der Valk 1981). Due to the ephemeral nature of annuals, perennials may serve as better wetland indicators. The most prevalent life history strategy among temporary pond aquatic species is represented by vegetatively reproducing perennials (van der Valk 1981).

Plant species may be considered drawdown species, standing water species, or generalists relative to propagule establishment (van der Valk 1981). The majority of emergent species germinate primarily on exposed areas free of vegetation. They require exposure to light and/or alternating extremes of temperature. Vegetative propagule formation may occur in response to drawdown and accompanying temperature changes (Gopal 1986). Submersed, free-floating, and floating-leaved species have seeds that require a flooded substrate for germination. There are also species that can be considered generalists which germinate in both exposed and inundated conditions (Gerritsen and Greening 1989). Relative species' abundances fluctuate due to modes of germination and frequency and duration of wet/dry cycles in the pond basins. Spatial gradients in seed bank density and viability may be later expressed in spatial patterns of adult populations and can result in patterns of zonation (Lowe 1986).

### **Structure of Vegetation in Temporary Ponds**

The distribution of water in time and space is the single most important factor influencing the occurrence of temporary pond macrophytes. Soil moisture is an important component. Plants in the temporary pond environment demonstrate a range of adaptations for tolerating inundation. Their distribution may follow hydrologic patterns and result in a zonation of vegetation in the pond basin (Laessle 1942; Lippert and Jameson 1964; van der Valk and Davis 1976; Abrahamson et al. 1984; Bridges and Orzell 1989; Kushlan 1990). Concentric

rings of different species and vegetative types can occur in temporary ponds as band-like divisions related to hydrology and slope (Lippert and Jameson 1964; Weller 1979). A typical pattern of zonation in a temporary pond has several discrete components, depending on soil moisture and the extent of flooding in the basin. The center of a flooded pond often contains floating-leaved plants. This inner zone is typically surrounded by vegetation with submerged roots growing in wet edges. Extending out from this zone, in damp ground surrounding the wet areas, is a band of tall and short emergents, such as sedges, rushes, and grasses. Other grasses and composites occur in drier margins of the ponds followed lastly by water-tolerant shrubs or trees in transitional zones (Lippert and Jameson 1964; Weller 1979; Kushlan 1990; LaClaire and Franz 1991). The bands of vegetation move back and forth across the pond basin in a reflection of changing soil moisture conditions (LaClaire and Franz 1991).

The wetland plants occurring in these basins have evolved adaptations to alternating wet/dry periods and often require this cycle of inundation/drawdown for their survival (van der Valk 1981). In other words, periodic water level changes, including periodic drought, are required for maintenance of the temporary pond plant community. The magnitude and frequency of the water level changes can be perceived as gradients of a normal environment along which the different wetland plants are distributed (Gopal 1986).

Basic information on the vegetation of temporary ponds in south and west-central Florida is available from several studies (Huffman 1982; Abrahamson et al. 1984; Botts and Cowell 1988), but a detailed description of the vegetation of temporary ponds in north and north-central Florida previously has been lacking. An overview of freshwater marshes in Florida was written by Kushlan (1990). He described zones of vegetation, determined by hydroperiod, elevation, and water depth, as typical of large highland marshes (central ridge of Florida) and flatwoods marshes (pine flatwoods). The zonation and species composition within these marshes have similarities to temporary ponds. Species in common with temporary ponds are described below. *Nymphaea* sp. Occurred in deep water centers with *Panicum hemitomon* on higher ground, intermixed with *Leersia hexandra*, *Juncus* sp., *Polygonum* sp., and *Lachnanthes caroliniana*. Farther upslope, *Rhynchospora inundata*, *R. tracyi* (flatwoods marsh), and *Eleocharis* sp. occurred. The uppermost zone of the flatwoods marsh, which completely dried-out each year, supported a wet prairie association with a variable species composition dominated by *Hypericum fasciculatum*, *Amphicarpum muhlenbergianum*, *Panicum abscissum*, and *Xyris* spp.. Flatwoods marsh terminated abruptly in a border of woody vegetation containing *Serenoa repens*, *Cephalanthus occidentalis*, *Salix* sp., *Fraxinus* sp., *Ilex glabra*, *Lyonia* sp., and slash pine (*Pinus elliotii*), or dry prairie.

*Panicum hemitomon* marshes dominated the higher ground on sandy substrates and typically had a *Sphagnum* mat. *Andropogon* spp. and *Spartina bakeri* were also mentioned as occurring in some marsh associations.



The distribution of vegetation within the temporary pond basin results from a predictable sequence of events summarized below (LaClaire and Franz 1991). There is a growth flush of aquatic and marsh vegetation following the rainy season.

As the pond basins begin to dry, the above-ground growth of most species gradually senesces and decomposes, leaving behind only seeds or below-ground vegetative propagules and roots. Upon completion of pond drying, another characteristic plant community appears. Species in this assemblage have short vegetative cycles and generally disappear before ponds refill. As soil moisture continues to drop, most plants disappear, and only those with fibrous stalks remain. In some instances, ruderal species may then move into the basins.

Fire can also be an important element in the distribution of wetland vegetation in temporary ponds. Fire suppression, for example, may result in fire intolerant species invading the pond basin and altering the plant community structure. *Panicum hemitomon* re-sprouts rapidly after fire and, as a result, can develop dense monotypic stands. Other plants, such as *Hypericum fasciculatum*, may be killed by fire, but their seeds are adapted to germinate after the plant has been burned.

## MATERIALS AND METHODS

### Description of Study Sites

The four sites selected for this study of temporary wetland vegetation were chosen because they contained breeding ponds for the Florida gopher frog and the striped newt. These amphibians occur in xeric conditions found in sandhill and scrub habitats, except during the breeding season, when they move to temporary ponds embedded within this landscape. Temporary ponds selected for study were located in north and north-central Florida and were associated with karst landscapes overlain by acidic, sandy soils. As a result of acids leaching from the pinelands through these well-drained soils, the limestone has slumped to form numerous sinkholes and depressions, some of which have developed into temporary ponds. Thirteen temporary ponds were chosen for study within the Apalachicola National Forest (ANF) in Leon County, the Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary (OSMP) and the Welaka Research and Education Center (WREC) in Putnam County, and the Ocala National Forest (ONF) located in Marion and Putnam counties. Of the 13 ponds, 9 were known breeding sites for either the striped newt or the gopher frog (Table 1). Unfortunately, due to the effects of drought, it could not be determined with certainty whether or not the remaining four ponds represented breeding sites for these species. However, the data obtained may be useful at a later date when amphibian surveys of these sites are completed. Individual pond names, designations, and basin descriptions are given below.

Table 1. Dimensions of all temporary pond basins studied. Amphibian breeding codes are: 0=unknown, 1=*Notophthalmus perstriatus*, 2=*Rana capito*, 3=both species.

Pond	Breeding Code	Dimensions of Pond Basins	
		N-S	E-W
ANF-1	1	50 m	64 m
ANF-3	3	83 m	80 m
ANF-4	3	35 m	70 m
GP	2	168 m	205 m
BP	3	95 m	95 m
OS	3	87 m	93 m
HP	3	105 m	100 m
DP	0	78 m	69 m
WE-5	0	45 m	93 m
WE-6	0	66 m	63 m
WE-11	0	82 m	96 m
LDP	1	105 m	103 m
RP	3	140 m	144 m

Vegetation of three ponds was sampled in ANF. The ponds were designated as ANF-1, ANF-3, and ANF-4 and were sampled in May 1990. In OSMP, the vegetation of five ponds, Gopher Pond (GP), Breezeway Pond (BP), One Shot Pond (OS), Harry Prairie Pond (HP), and Dry Pond (DP) was sampled in June and July 1990. Breezeway Pond and GP were also sampled in October and November 1989, and the results of that survey are included (LaClaire and Smith unpubl. MS). Vegetation of three ponds in WREC was also sampled in July 1990; pond designations are WE-5, WE-6, and WE-11. Qualitative plant lists were compiled for Lake Delancy Pond (LDP) in ONF and Recess Pond (RP) located on private property adjacent to OSMP. Lake Delancy Pond was sampled January 1990 and June 1991, and RP was sampled every 10 days May through August 1991 as part of another study (LaClaire unpubl. data).

The size of the pond basins, estimated from north-south and east-west axes terminating at the pond/upland boundary, ranged from less than a hectare to approximately 3 hectares (Table 1). These ponds were dominated by grasses, sedges, and herbaceous vegetation, and none were forested wetlands. All of the ponds had historical breeding records for either the Florida gopher frog or the striped newt with the exception of Dry Pond in OSMP and the ponds located in WREC. Dry Pond was selected because it had been dry for at least seven years prior to the study and represented an extreme in length of the dry phase of temporary ponds. The ponds in WREC were thought to represent potential breeding ponds for the Florida gopher frog. The gopher frog is known to occur in

gopher tortoise burrows on site near the ponds (R. Franz pers. comm) but has not been studied in its breeding habitat.

The history of pond drying and re-filling at each site was obtained from knowledgeable sources whenever possible. Unfortunately, hydrologic data were only partially available for the study ponds. The ANF ponds had the longest known hydroperiod and the OSMP ponds the shortest. Since the hydroperiod of each pond could not be compared, inferences about hydrology are based on the only variable known for each pond, months since the pond had held water when it was sampled.

**Apalachicola National Forest.**-- The Apalachicola study area is located in a region called the Lake Munson Hills on the northwestern portion of the Woodville Karst Plain and in the extreme northeastern corner of the ANF (USDA 1984). The study ponds, ANF-1, ANF-3, and ANF-4, have formed on depressions located on well-drained Ortega sands. These ponds are described in an article by Means (1990). The surrounding forest is composed of native longleaf pine (*Pinus palustris*) with some slash (*P. elliotti*) and loblolly pine (*P. taeda*) and is managed for timber production by the USDA Forest Service. A few scattered oaks surround the pond basins.

**Katharine Ordway Preserve-Carl Swisher Memorial Sanctuary.**-- The OSMP is located on the Interlachen Karst Plain at the southern flank of Trail Ridge in western Putnam County (Franz and Hall 1991). This is an area of extensive sandhills underlain by well to excessively drained Candler-Apopka soils. The vegetation surrounding the five OSMP ponds and the adjacent RP consisted of longleaf pine/turkey oak (*Quercus laevis*) forests and xeric oak hammocks that are typical elements of sandhill communities.

From the Soil Survey of Putnam County (Readle 1990), some discrimination of soil types can be made in the pond basins. Gopher Pond, BP, and HP were mapped as Placid fine sand, depressional. This soil is in depressional areas on the uplands and has a high available water capacity in the surface layer. Gopher Pond and BP are on the outer fringes of lake basins, and under extreme high water, perhaps a hundred year flood, they would be contiguous with them (USGS map, circa 1935). Harry Prairie Pond is at the outer edge of a wet prairie system but separated from it by a low sand ridge. A connection with the prairie would be possible under extreme high water. Dry Pond was mapped as Ona fine sand, a poorly drained soil typical of ponded areas. One Shot Pond was the only pond in which the soil of the pond basin was not specifically described, because it was improperly mapped as a perennial pond by the Putnam County soil survey (Readle 1990).

**Welaka Research and Education Center.**-- The WREC lies to the east of the St. John's River valley on an isolated ridge of Candler-Apopka soils and sandhill and scrub vegetation (Readle 1990). The study ponds, WE-5, WE-6, and WE-11,

differ from those described above in that they are adjacent to or imbedded within flatwoods (Laessle 1942). Pond WE-5 was located in an area of Placid fine sand, depressionnal, downslope from longleaf pine/turkey oak sandhills. Pond WE-6 was also downslope from longleaf pine/turkey oak sandhills but was bordered on one side by upland hardwoods such as Chapman's oak (*Q. chapmanii*) and myrtle oak (*Q. myrtifolia*) which are associated with sand pine (*P. clausa*) scrub habitat. The soil mapped here was Pomello fine sand, which is a flatwoods soil with an organic pan below the surface. Pond WE-11 was a flatwoods pond mapped with Pomona fine sand, a poorly drained sand over a loamy subsoil (Puckett 1982). It was near a xeric hammock located on deep sands and containing live oak (*Q. virginiana*) and longleaf pine.

**Ocala National Forest.**-- Lake Delancy Pond, located in a section of the ONF in southern Putnam County, is an area of sand pine scrub managed by the USDA Forest Service for timber production. It is located on moderately well drained Pomello sand (T. Bailey pers. comm), and the natural vegetation of the area is sand pine, slash pine, scrub live oak (*Q. geminata*), myrtle oak, and saw palmetto (*Serenoa repens*). Approximately 2 km to the east is a sand ridge of Astatula soils that supports forests of longleaf pine and turkey oak. Just prior to the initiation of this study, the forest surrounding the pond had been clear-cut, bedded and replanted with sand pine. A thick layer of muck and algae were present in this pond and it held water through-out the period of this study without drying.

**Climatic conditions.**-- Average daily temperatures, annual precipitation, and weather patterns are similar between the Putnam County study sites and the ANF in Leon County (USDA, 1984; Readle, 1990). The average daily temperature for both areas in summer is 27° C and in winter ranges from 11° C (ANF) to 12° C (Putnam County). Annual precipitation ranges from approximately 142 cm per year (Putnam County) to 152 cm per year (ANF). Most of the precipitation occurs in the summer as a result of convective thunderstorms. October and November are the driest months. Rain occurring in the winter results from frontal depressions that originate in the northern U.S. and Canada. Water tables in uplands of north and north-central Florida have seasonal highs in the winter and lows in the summer.

### Field Methods

Single linear transects were established in each pond by taking a compass heading of 0° N at the center of each pond and walking perpendicular to the topographic gradient to the surrounding upland edge. The 1989 sampling of BP and GP deviated from this compass heading. A random compass direction was selected for these two transects. Sampling points were begun at the center of each

pond and located at 5 m intervals until the upland boundary, as indicated by vegetation (pines or oak hammock), was reached (Abrahamson et al. 1988). If the next 5 m sampling point along the transect was completely within upland habitat, the sampling was terminated at the previous location. Transect lengths varied from 25 to 80 m depending on the size of the pond basin. At each of the sampling points, percent ground cover was sampled within quadrats using a rectangular vegetation sampling frame with dimensions 0.5 m x 2.0 m. To facilitate ocular estimation of cover, 0.1 m portions of the sampling frame were shaded. Percent cover was estimated for all plants (< 1 m tall or non-woody) rooted within the quadrat. Plants were identified to the species level where possible. Bare soil (classified as unvegetated), dead vegetation, surface water, and non-vascular plants were also given cover estimates. In one pond (BP, 1989 sampling), a distinction was made between a ground cover layer and a shrub layer. Shrubs, defined as woody plants greater than 1 m in height, were sampled using 5 m x 5 m quadrats located at 5 m intervals along the transect. In all other pond basins, shrubs at the transect sampling locations were sampled within the same 1 m square quadrat as the ground cover layer.

During each sampling in 1989 and 1990, a survey of the flora was made after the transect sampling. Circuits were made around the pond basins from the center to the upland boundary to opportunistically identify additional species missed on the transects. This method of sampling was also used to obtain species presence/absence data for LDP and RP.

### Data Analysis

Analyses were chosen to address the research objective and to fit the field methods used. Plant lists were compiled for each site. Plant species identification and nomenclature follow Wunderlin (1982) and Clewell (1985). Only those 11 ponds sampled using transects during 1989 and 1990 were used in calculations. Total species occurrence data in all ponds, including LDP and RP, were used to make comparisons between sites.

To determine the similarities between the plant community at each pond, a number of different methods was used. The most common plant species were determined by finding those present in greater than 60% (7/11) of the ponds. Sixty percent was an arbitrary limit set as indicative of presence in a high percentage of samples, and plants found with this frequency were considered "constant" species (Mueller-Dombois and Ellenberg 1974). The most common plant species were identified from the 1990 transect data alone, then the 1989 transect data and data from the circuit searches were added, and the most common plant species were determined from the combined samples.

Percent cover values were used to calculate the dominant species in each pond basin and for all ponds combined using the 1989 and 1990 transect data. The top three species were chosen as co-dominants from a list of total percent cover ranked from highest to lowest.

The floristic similarity between sites was determined using Sorensen's index of similarity (SI) (Mueller-Dombois and Ellenberg 1974). This index was calculated from species presence/absence and transect data from 1989 and 1990. It is computed as follows:

$$SI = \frac{2C}{A+B} \times 100$$

A = # species, site 1  
 B = # species, site 2  
 C = # species, common  
       to both sites

The results from the calculation of similarity indices were used to compare species composition in patterns of zonation previously reported in the literature and determine if similar patterns were present in the study ponds.

To determine if the vegetation of each pond corresponded to an index value indicative of wetland, species identified within quadrats were categorized by their wetland indicator status and given an associated ecological index value (EI) (Table 2) (Reed 1988; Wentworth et al. 1988). Ecological index values range from 1, for obligate wetland species, to 5, for obligate upland species. Plus (+) and minus (-) designations specify, respectively, the higher (more frequently found in wetlands) or lower (less frequently found in wetlands) part of the frequency range for a particular species. When assigning the EI, species with a plus received 0.5 less than the EI for that category and species with a minus received 0.5 more than the EI for that category. Plants identified only to genus were assigned the maximum indicator status category and the maximum EI if there were differences within the genus. A plant community consists of hydrophytic vegetation if visually estimated percent cover of obligate wetland species (OBL) and facultative wetland species (FACW) exceeds coverage of facultative upland species (FACU) and obligate upland species (UPL) or if the EI < 3 (USEPA 1989; USEPA 1991).

Wetland index values (WIV) were calculated for each quadrat for each transect across all ponds and all years using weighted averages of the percent cover data (Wentworth et al. 1988). To calculate this index, relative abundance (R) of each species in each quadrat was determined as percent cover of each individual species divided by the total percent cover of all species in that quadrat. Calculation of the WIV involved taking the sum of products of the relative abundances and ecological index values of all species in each quadrat, divided by the sum of all the relative abundances, as follows:

$$WIV = \frac{\sum (R \times EI)}{\sum R}$$

R = Relative abundance  
 EI = Ecological index value



Table 2. Wetland Indicator Status and Ecological Index Values (EI) (Reed 1988; Wentworth et al. 1988).

Category	Symbol	Definition	EI
Obligate Wetland	OBL	Plants that occur almost always in wetlands under natural conditions (estimated probability > 99%).	1
Facultative Wetland	FACW	Plants that usually occur in wetlands (estimated probability > 67% to 99%) but also occur in non-wetlands (estimated probability 1% to 33%).	2
Facultative	FAC	Plants with a similar likelihood of occurring in both wetlands and nonwetlands(estimated probability 33% to 67%).	3
Facultative Upland	FACU	Plants that sometimes occur in wetlands(estimated probability 1% to 33%), occur more often in non-wetlands (estimated probability > 67% to 99%).	4
Obligate Upland	UPL	Plants that occur rarely in wetlands (estimated probability < 1%) but occur almost always in non-wetlands under natural conditions(estimated probability > 99%).	5

Percent cover data from each pond transect were used in conjunction with the wetland indicator status of each species to determine the total percent cover in each pond basin of OBL, FACW, FAC, FACU, and UPL species. These data were compared by hydrologic status of each pond as expressed by months since each pond had held water.

Species richness, Shannon's Index, and evenness were calculated for each set of pond transect data. These data were also compared by hydrologic status at each pond as expressed by months since each pond had held water. Species richness is the total number of species found along each pond transect. Shannon's Index,  $H'$ , is a measure of the average degree of "uncertainty" in predicting the species of an individual chosen at random from a collection of  $S$  species and  $N$  individuals in a population (Shannon and Weaver 1949). As diversity increases, Shannon's Index will also increase. The equation describing Shannon's Index is as follows:

$$H' = - \sum (p_i \ln p_i)$$

$p_i$  = proportional abundance of each species; estimated from the proportion of the number of individuals of a species to the total number of individuals in the sample.

Evenness,  $E$ , was calculated as the ratio of  $H'$  to the natural log of species richness. Evenness would be maximum when all species were equally abundant and would decrease toward zero as the community diverged from evenness.



## RESULTS

A total of 112 vascular plant species were identified in the 13 ponds across all 3 sampling years. An additional 12 plants were only identifiable to genus. Of the 112 species, 30% were identified in only one of the 11 ponds for which there were transect data; 64 (57%) were identified from the transect data alone; and the balance of the species were identified from circuit searches made through the pond basins. Of the species, 15% were present only in RP and 4% only in LDP. Of the 12 plants identified only to genera, 8 were the same genera as an identified species and may have been one of those species. In addition to the vascular plants, three groups of nonvascular plants were identified. Algae, *Cladonia* sp., and *Sphagnum* sp. were present as ground cover in pond basins.

Only two species, *Panicum hemitomon* and *Andropogon glomeratus*, were present in 60% of the ponds for which there were transect data (Table 3). However, if the data for all ponds are combined, an additional six taxa are present in at least 60% (8) of the 13 ponds. These include *Rhexia mariana* var. *mariana*, *Eupatorium leptophyllum*, *Rhynchospora* spp., *Ilex glabra*, *Cephalanthus occidentalis*, and members of the family Eriocaulaceae. *Rhynchospora* spp. and members of the family Eriocaulaceae were lumped together because of the similar habitat requirements of individual species and their similar zonation within pond basins.

Co-dominant species in the 11 pond basins (Tables 4, 5) were represented by 21 vascular and 2 nonvascular plants. *Panicum hemitomon* had the highest total percent cover in seven of the ponds. It was also a co-dominant in two additional ponds, resulting in co-dominance in 82% of the ponds with transect data. Of the co-dominant species, 78% were present in only one pond, 3 species were co-dominant in two pond basins, and *Eupatorium leptophyllum* was co-dominant in three ponds. Two non-vascular plants, *Sphagnum* sp. and *Cladonia* sp., were each co-dominant in one pond. Of the vascular plants determined to be co-dominants, 52% were OBL, 33% were FACW, 10% were FAC, and 5% were FACU species. No UPL species (Reed 1988) were co-dominants, but *Cladonia* sp. is an upland associated species.

Similarity indices indicated that the similarity between ponds was generally low. There were less than 50% shared species between most pond basins (Table 6). Of the transects sampled in 1990, only five pairwise comparisons of pond vegetation (9%) had greater than 50% of their species in common. When the data collected in 1989 from the two transects in BP and GP were compared to each of the sets of data from the 1990 ponds, only the samples of vegetation from BP and GP shared greater than 50% of their species. The WREC ponds were the least similar to other ponds. The lowest SI was calculated when WE-5 and WE-11 were compared with OS. Similarity indices were highest when the ANF ponds were compared to each other.

Table 3. Plant species present on greater than 60% of 1990 transects (1990) OR in greater than 60 % of all pond basins (ALL), data combined.

Plant Species	1990	All
<i>Panicum hemitomon</i>	11/11	13/13
<i>Andropogon glomeratus</i>	8/11	13/13
<i>Rhexia mariana</i> var. <i>mariana</i>	—	11/13
<i>Eupatorium leptophyllum</i>	—	10/13
Eriocaulaceae	—	9/13
<i>Rhynchospora</i> sp.	—	8/13
<i>Ilex glabra</i>	—	8/13
<i>Cephalanthus occidentalis</i>	—	8/13

Table 4. Percentage of total vegetated cover for each co-dominant species from transects in Apalachicola National Forest (ANF) and Welaka Research and Education Center (WE), 1990. WIS=Wetland indicator status (Reed 1988).

Species	WIS	Pond					
		ANF-1	ANF-3	ANF-4	WE-5	WE-6	WE-11
<i>Sphagnum</i> sp.	N/A					6	
<i>Dichanthelium erectifolium</i>	OBL		32	18			
<i>Panicum hemitomon</i>	OBL			8	34	65	54
<i>Rhynchospora corniculata</i>	OBL						15
<i>Rhynchospora glomerata</i>	OBL				20		
<i>Eriocaulon</i> sp.	OBL	13					
<i>Nymphaea odorata</i>	OBL						23
<i>Lachnanthes caroliniana</i>	OBL				16		
<i>Ranunculus sceleratus</i>	OBL	18		48			
<i>Andropogon glomeratus</i>	FACW		11				
<i>Fimbristylis schoenoides</i>	FACW					18	
<i>Eupatorium leptophyllum</i>	FAC+		26				
<i>Dichanthelium acuminatum</i>	FAC	24					
Total % Cover 3 sp. combined	—	55	69	74	70	89	92

Species	WIS	Pond						
		GP (1989)	GP	BP	BP (1989)	OS	HP	DP
<i>Axonopus furcatus</i>	OBL			19	→			
<i>Leersia hexandra</i>	OBL	22	16					
<i>Panicum hemitomom</i>	OBL	39	12	52	29	22	44	59
<i>Eleocharis rostellata</i>	OBL					14		
<i>Lachnocaulon anceps</i>	OBL			9				
<i>Rhexia mariana</i>	FACW+						10	
<i>Panicum verrucosum</i>	FACW		30		35			
<i>Cyperus odoratus</i>	FACW					22		
<i>Ilex glabra</i>	FACW	7						
<i>Eupatorium leptophyllum</i>	FAC+			20			14	
<i>Pinus palustris</i>	FACU+							13
<i>Cladonia</i> sp.	N/A							15
% Total Cover								
3 sp. combined	—	68	58	81	83	58	68	87

[illegible]

Table 7. Wetland Index Values calculated from transect vegetation data and Wetland Indicator Values. All ponds sampled in 1990 except GP and BP as indicated. M=meters from pond center.

M	ANF 1	ANF 3	ANF 4	GP 90	GP 89	BP 90	BP 89	OS	HP	DP	WE 5	WE 6	WE 11
0	1.03	1.00	1.00	1.20	1.04	1.90	1.90	2.02	1.33	1.04	1.00	1.35	1.00
5	1.25	1.00	1.11	1.09	1.31	1.71	2.08	1.68	1.09	1.59	1.00	1.06	1.00
10	1.22	1.52	1.14	1.09	1.39	2.45	1.36	2.75	2.61	1.05	1.00	1.42	1.00
15	1.72	1.71	1.00	1.17	1.22	1.43	1.76	1.49	1.12	1.33	1.20	1.36	1.00
20	2.74	1.46	1.00	1.00	1.56	1.00	1.18	1.00	1.21	2.72	1.00	1.02	1.00
25	1.50	1.70	1.30	1.00	1.85	1.04	1.04	1.31	1.93	3.03	3.75	3.33	1.00
30	—	1.97	1.41	1.00	1.55	1.08	1.00	1.70	1.79	3.71	—	—	1.00
35	—	1.63	—	1.00	1.70	1.02	1.00	1.81	1.26	3.41	—	—	1.05
40	—	2.14	—	1.00	1.44	1.47	1.00	3.00	1.59	3.66	—	—	1.05
45	—	—	—	1.00	2.00	—	1.00	3.53	1.88	—	—	—	2.15
50	—	—	—	1.15	—	—	—	—	—	—	—	—	—
55	—	—	—	1.00	—	—	—	—	—	—	—	—	—
60	—	—	—	1.15	—	—	—	—	—	—	—	—	—
65	—	—	—	1.80	—	—	—	—	—	—	—	—	—
70	—	—	—	1.77	—	—	—	—	—	—	—	—	—
75	—	—	—	2.04	—	—	—	—	—	—	—	—	—
80	—	—	—	2.57	—	—	—	—	—	—	—	—	—
MEAN	1.58	1.57	1.14	1.30	1.51	1.46	1.33	2.03	1.58	2.39	1.49	1.59	1.13

Table 8. Percent Cover by Wetland Indicator Status, 1990 transects. 0 months since water indicates a pond was flooded when sampled.

Pond	Months Since Water	Total Percent Cover				
		OBL	FACW	FAC	FACU	UPL
ANF-1	1	51	22	26	<1	0
ANF-3	0	48	23	29	0	<1
ANF-4	0	90	5	5	1	0
GP	12	72	23	2	2	1
BP	19	62	18	20	0	0
OS	4	41	45	9	3	2
HP	16	46	34	14	6	0
DP	84	69	3	1	27	<1
WE-5	0	81	4	3	13	0
WE-6	0	72	26	0	2	0
WE-11	0	96	3	0	1	0

Table 9. Species richness (S), Shannon's Diversity Index (H'), and Evenness (E) calculated from the 1989 and 1990 transect data. 0 months since water indicates that ponds were flooded when sampled.

Pond	Months Since Water	S	H'	E
ANF-1	1	15	2.07	0.76
ANF-3	0	16	1.91	0.69
ANF-4	0	15	1.71	0.63
GP (90)	12	17	1.92	0.68
GP (89)	4	15	2.14	0.79
BP (90)	19	10	1.42	0.61
BP (89)	11	13	1.66	0.65
OS	4	19	2.28	0.77
HP	16	12	1.81	0.73
DP	84	9	1.30	0.59
WE-5	0	11	1.76	0.74
WE-6	0	11	1.17	0.49
WE-11	0	9	1.29	0.59

Wetland index values were calculated for each quadrat for each vegetation transect in 1989 and 1990, and a mean was calculated for each pond (Table 7). The lowest mean value was 1.13 in WE-11, and the highest mean value was 2.39 in DP. These results are to be expected since, at the time of sampling, all Welaka ponds were flooded, and DP had been dry longer than any other study pond. Calculation of the total percent cover along the transects in each pond basin for each category of wetland indicator class revealed that all ponds except OS had OBL species as the largest component of total percent cover (Table 8). In OS, there was only a slightly higher percent cover of FACW when compared to OBL (4%). Even DP, which had been dry for at least 84 months, maintained a total percent cover of OBL of 69%.

Species richness (Table 9) ranged from a low of nine species in DP and WE-11 to a high of 19 species in OS. The ponds in ANF had the highest average species richness, and the WREC ponds had the lowest. Species richness in ONF ponds was similar to that in the ANF ponds. Among the ANF ponds and among the WREC ponds, species richness was similar, but OSMF ponds varied from the lowest to the highest number of species. Species richness was very high in RP, but, this result was expected since the number of vegetation samples obtained from this site were much higher than any other pond basin.

Calculation of Shannon's Index (H') resulted in a range of values from 1.17 in WE-6 to 2.28 in OS (Table 6). Evenness (E) ranged from 0.49 in WE-6 to 0.79 in

GP(1989) (Table 9). The amount of time since each pond had held water when sampled is also presented in Table 9.

## DISCUSSION

### Pond Similarities and Differences

The similarities found in plant community composition between ponds was based primarily on the presence of the eight most commonly found taxa and the study site within which each pond was located. Both similarities and differences between ponds were related to differences in each pond's hydrologic cycle, as measured by the time since each pond had held water. This related directly to soil moisture conditions (LaClaire 1992). Flooded ponds lacked some of the dry meadow species but had floating-leaved species that were absent from the dry ponds. Dry meadow species and plants responding to declines in soil moisture conditions were more abundant in dry pond basins. This is demonstrated by the low similarity when WE-5 and WE-11 are compared to OS. The flooded WREC ponds had greater than 80% total cover of OBL but very low total percent cover of FACW (4% and 3% respectively). One Shot Pond, which had been dry for 4 months when sampled, had 41% total cover of OBL and 45% FACW. The FACW species were responding to drawdown and specific moisture conditions for which they are adapted.

Only four of the study ponds were sampled when drawdown had been recent, and ruderal or annual/short-lived perennial type species, except for *Eupatorium leptophyllum*, were not common in the pond basins. The transects in BP and GP from 1989 and OS were sampled when drawdown had occurred less than 1 year previous. One pond, ANF-1, had been dry only for a month when sampled, but this was too soon for emergent vegetation to respond to the change in the environment. All the other ponds were either flooded or had been dry a year or longer. As a result, most of the co-dominant species identified in the ponds were perennials, as were most of the total species identified across all ponds and all years. Of course, additional species may have been present as vegetative propagules or as seeds in the seed bank of ponds. Since annuals have a short life cycle, frequent sampling would be required for a complete species list.

Differences between the ponds are obvious from the fact that 78% of the co-dominant species identified in each pond were present in only one pond. However, many of these co-dominant species, as well as other component species of the ponds, shared life histories that were in some way adapted for the cyclic changes in the temporary pond basin. The most obvious similarity was the dominance of perennial species in the ponds. Other similarities involved adaptations developed in response to changes in hydrologic cycle. Several species (*Dichanthelium sabulorum*, *Juncus repens*, and *Sagittaria graminea*) showed a wide range of shoot



and leaf growth forms or growth phases depending on soil moisture conditions. Others (for example, *Hypericum fasciculatum*) had a needle-like leaf form typical of many stress tolerant species (Grime 1979). Other species responded in the same way to a particular stage in the hydrologic cycle. This can be seen in ponds where drawdown had been recent. Some plants represented species that colonize the bare mud which becomes available after drawdown. Rapid plant growth was supported by the nutrient-rich, moist soil present in a temporary pond at this time. The period available for growth may be relatively short, and, thus, these species were annuals with a high potential growth-rate or short-lived perennials that were adapted to exploit this intermittently favorable environment (Grime 1979). *Panicum verrucosum* (an annual) is an example of this type of strategy. It had the highest percent cover on the 1989 transects in BP and GP and had set seed at the time of sampling. In 1990, the species was not found in either BP or GP. It is likely that its disappearance reflects the declining level of soil moisture between sampling events (LaClaire 1992) and that continued drought conditions did not favor seed germination. Another example of a drawdown species is the annual or short-lived perennial, *Cyperus odoratus*. It shared the highest percent cover with *P. hemitomon* on transects in OS. It occurred at the lowest elevation in the pond center and disappeared shortly after it set seed (LaClaire unpubl. data). This result fits a pattern where the deep area of a pond or marsh changes community composition seasonally depending on drying conditions (Botts and Cowell 1988). A perennial species, *Eupatorium leptophyllum*, was co-dominant in BP (1990), HP, and ANF-3. This ruderal species is also adapted to exploit the bare soil exposed after the pond dries. However, it requires less soil moisture, as indicated by its FAC+ status, and so moves into the pond basin later in the pond drying cycle than *P. verrucosum* or *C. odoratus*. It occurred throughout the pond basins when soil was exposed and moisture conditions were appropriate.

Some differences between ponds can be explained by differences in the surrounding habitat. Low similarity between the WREC ponds and other study ponds can be explained partly by the association of flatwoods vegetation with the WREC ponds and not the other study sites. Another explanation may relate to the selection of these ponds for study. None of the ponds at WREC has been verified as breeding ponds for the Florida gopher frog or the striped newt. If they are not, in fact, breeding sites, this may relate to differences in the pond plant communities. The higher similarities that resulted when ponds were compared within study sites suggests other unknown habitat variables.

*Panicum hemitomon* was the only species present in every pond sampled. The distribution of this species was a good indicator of the extent of previous flooding in the pond basin, and its highest elevation in each pond roughly corresponded to the average high water mark (Abrahamson et al. 1984; Lowe 1986; LaClaire unpubl. data). *Panicum hemitomon* cannot tolerate long-term flooding, and, thus, its absence in flooded pond centers demonstrated a persistent flooding event. The above-ground growth of *P. hemitomon* tends to be fibrous and resistant to

composition. Its stalks may remain standing even if a pond has not filled for several years, and it is able to survive many years of dry pond conditions, as exemplified by the results from DP. Due to its tendency to grow in thick, monotypic stands, it probably acts to maintain the wetland environment by inhibiting the growth of upland species and reducing the oxidation of the soil organic matter that is crucial for nutrient cycling in the pond basin. In this way, *P. hemitomon* protects the wetland environment; the hydric soil and seedbank remain intact until another flooding event.

### Pond Zonation

The results of this study and previous work in upland temporary pond basins in south and north-central Florida (Franz and Hall 1991; LaClaire and Franz 1991; LaClaire 1992) have revealed a pattern of zonation with similarities to other descriptions of temporary ponds (Fig. 1). Water-filled ponds often contain floating-leaved plants and submergents in the deepest areas (Water Lily Zone) and tall and short emergents at the pond edge (Sedge Prairie Zone). When the ponds dry, emergent grasses fill these zones in the previously flooded portions of the basin. Further upslope, a band of *Hypericum fasciculatum* (Sandweed Zone) commonly occurs, typically followed by a band of *Andropogon* spp. (Bluestem Grass Zone). Continuing upslope, additional bands of vegetation are found in dry shadows (Dry Meadow Zone) that occur as transitional zones adjacent to the upleaf pine dominated uplands. In some ponds, a fire shadow is present upslope of the Dry Meadow Zone which contains fire intolerant evergreen shrubs (Evergreen Shrub Zone) and oaks (Xeric Hammock Zone).

The two most common plant species found in the study ponds, *Panicum hemitomon* and *Andropogon glomeratus*, created the most obvious zonation in the study basins overall. Both of these species are perennials with tall, persistent stems that are resistant to decomposition. *Panicum hemitomon* was the dominant species in the Sedge Prairie Zone and often defined its boundaries. *Andropogon glomeratus* defined the Bluestem Grass Zone. In temporary ponds, *P. hemitomon* reproduces most commonly vegetatively, but *A. glomeratus* sets seed that are wind-dispersed. The result of these differences in reproduction can partially explain overlapping zones in some of the ponds. *Panicum hemitomon* occurred generally in a uniform zone. *Andropogon glomeratus* was generally present along the outer edges of the pond, but it was also present in dry pond centers probably as a result of conditions appropriate to its seed germination.

The six additional species considered most common in the combined data sets represented typical plants of temporary pond zones with the exception of *Spartina leptophyllum*. Species dominance and the extent of zonation within

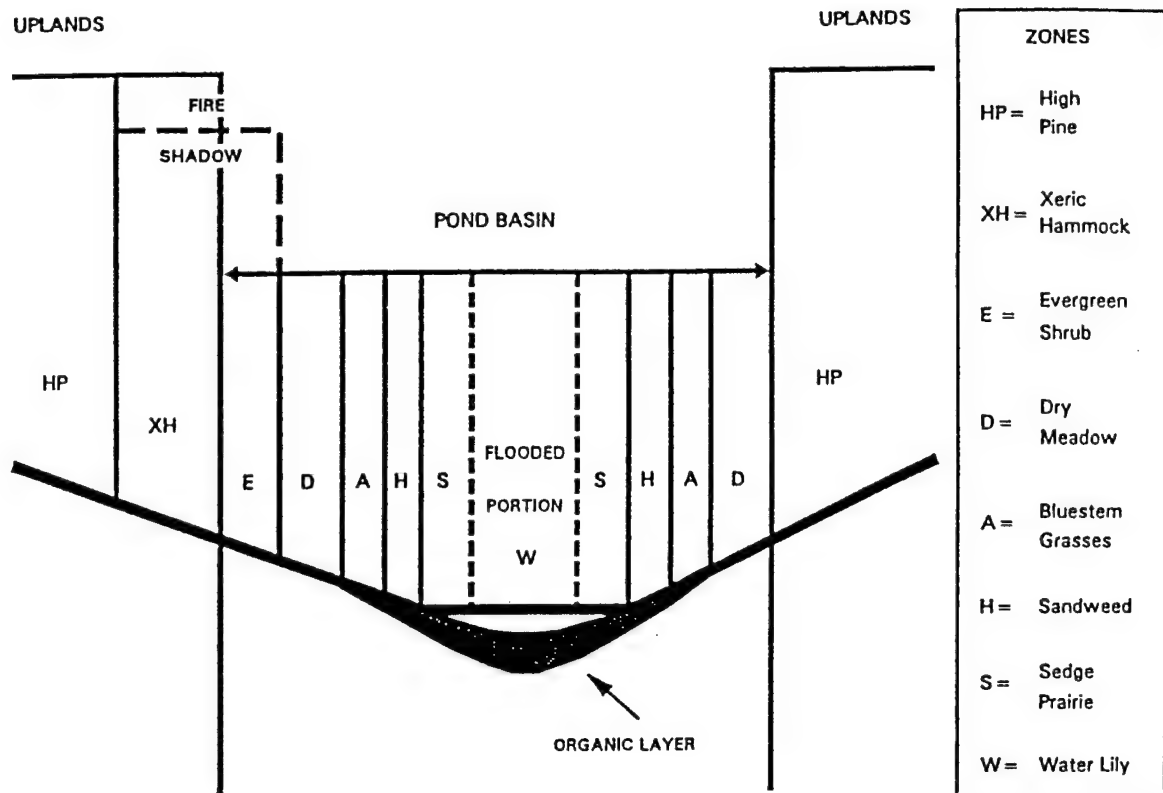


Figure 1. Plant community structure in temporary pond basins.

each study pond varied depending on water depth or, if ponds were dry, on how recently ponds had held water. *Rhynchospora* spp. and members of the family Eriocaulaceae were the most common plants in the Sedge Prairie Zone after *Panicum hemitomon*. These species were co-dominant in flooded ponds and those recently dried (ANF and WREC ponds, OS) and less common in ponds that had been dry longer. *Rhexia mariana* var. *mariana* occurred as part of the Dry Meadow Zone. Two shrubs, *Ilex glabra* and *Cephalanthus occidentalis*, were also "constant" species in the study ponds. They are typical members of the Evergreen Shrub Zone and are indicative of a lack of fire in at least part of the basin.

The most common species, and their representative patterns of zonation, have been described from other ponds with fluctuating water levels in similar habitats on the lower coastal plain (Huffman 1982; Abrahamson et al. 1984; Lynch et al. 1986; Botts and Cowell 1988; Bridges and Orzell 1989). The most common overlap between the study ponds and the literature were the grasses, sedges and herbs of the Water Lily and Sedge Prairie Zones such as species of *Panicum*, *Rhynchospora*, *Xyris*, and the Eriocaulaceae. Other dominant species frequently mentioned in the literature were *Hypericum fasciculatum* and *H. myrtifolium*

Sandweed Zone), *Andropogon glomeratus* (Bluestem Grass Zone), and *Rhexia mariana* var. *mariana* (Dry Meadow Zone).

The importance of seed banks in maintaining the temporary pond community was not addressed directly in this study. However, the seed bank is likely to be very important to the maintenance of the wetland community and a contributing factor to pond zonation. Many wetland plant species disperse floating seeds and/or require specific intervals of inundation or desiccation for seed germination (van der Valk 1981). The position of these species may be dependent on the extent of flooding in the basin before drawdown, as well as the duration of drawdown (Lowe 1986; Hull et al. 1989). An overlapping distribution of plant species perhaps indicates similar hydrologic tolerances, but it may also indicate similar suitability of the substrate for seed settling, seed germination, and plant growth after the seeds have dispersed to that position (Hull et al. 1989).

### Wetland Index Values (WIV)

All of the temporary pond basins studied had WIV less than 3, and, as a result, their plant communities can be considered wetland vegetation according to the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (USEPA 1989). Wetland index values generally increased along the transects as the upland boundary was reached. However, there was not a simple relationship between the index values and a gradient of soil moisture, described by meters from the pond center, because of confounding elevation and substrate effects (LaClaire unpubl. data). The lowest mean WIV was calculated for WE-11. This was the result of the most complete dominance (96%) of this pond basin by OBL. The highest mean WIV was calculated for DP and was a result of the co-dominant UPL species found at it. However, DP maintained OBL as the highest total percent cover and, as a result, maintained its status as wetland.

### Species Richness, Diversity, and Hydrology

The relationship between status of each pond in its hydrologic cycle, as presented by time since it was flooded, and species richness and diversity is complex. The lowest species richness was found in DP, which had been dry longer than any other pond basin, but also in WE-11, which was flooded at the time of sampling. Both ponds had low values for evenness as a result of dominance by *Eleocharis acicularis*, 59% of total cover for DP and 54% of total cover for WE-11. Melaka pond #11 was almost entirely flooded (35/45 m along the transect) and this

Table 10. Typical species of pond zones and their occurrence within study areas of ANF (1), WREC (2), OSMP (3), and ONF (4). LF=Life form: A=annual, P=perennial, A/P=annual or short-lived perennial, S=shrub, T=tree. Pond Zone: W=water lily, S=Sedge Prairie, H=Sandweed, A/DM=Andropogon/Dry Meadow, E=Evergreen Shrub, XH=Xeric Hammock, HP=High Pine.

LF	Species	Pond Zone						
		W	S	H	A/DM	E	XH	HP
P	<i>Sagittaria graminea</i>	1,3						
P	<i>Pontederia cordata</i>	2						
P	<i>Nuphar luteum</i>	3,4						
P	<i>Nymphaea odorata</i>	2,4						
P	<i>Polygonum</i> spp.	1,2,3						
A/P	<i>Ranunculus scleratus</i>	1						
P	<i>Dichanthelium erectifolium</i>		1,2,3					
P	<i>Panicum hemitomon</i>		1,2,3,4					
A	<i>Panicum verrucosum</i>		3					
A/P	<i>Cyperus</i> spp.		3					
A/P	<i>Eleocharis</i> spp.		2,3					
P	<i>Fimbristylis</i> spp.		2,3					
A	<i>Psilocarya scirpoides</i>		3					
P	<i>Rhynchospora</i> spp.		1,2,3,4					
P	<i>Juncus repens</i>		1,3					
P	<i>Eriocaulon</i> sp.		1,2,3					
P	<i>Lachnocaulon anceps</i>		3,4					
P	<i>Lachnanthes caroliniana</i>		2,4					
A/P	<i>Xyris</i> spp.		2,3,4					
S	<i>Hypericum fasciculatum</i>			1,3				
P	<i>Amphicarpum muhlenbergianum</i>				1,2,3			
P	<i>Andropogon glomeratus</i>				1,3,4			
P	<i>Rhexia mariana</i> var. <i>mariana</i>				1,2,3			
S	<i>Ilex glabra</i>					1,2,3,4		
S	<i>Ceratiola ericoides</i>					3		
S	<i>Lyonia lucida</i>					2,3		
S	<i>Lyonia mariana</i>					1,4		
S	<i>Vaccinium</i> spp.					1,3		
S	<i>Serenoa repens</i>						2,4	
T	<i>Quercus geminata</i>						1,3,4	
T	<i>Pinus elliottii</i>							1,2,3,4
T	<i>Pinus palustris</i>							1,2,3,4

contributed to its low species richness and diversity due to domination of the pond by a few obligate wetland species. In contrast, the ANF ponds were flooded only along short lengths of the vegetation transects. The higher species richness and diversity in ANF ponds was a reflection of the more variable moisture regime and, thus, greater habitat complexity. The highest species richness and diversity, and second highest level of evenness, were found in OS, which had been dry for 4 months when the vegetation was sampled.

Clarification of this pattern is possible when co-dominant species and their corresponding wetland indicator status are considered. In DP, the second and third ranked most abundant vegetative cover along the transect represented species that were either facultative upland or upland associated. In WE-11, however, all three of the co-dominant species were obligate wetland plants. The co-dominant species

in OS were a mix of obligate and facultative wetland species. The high species richness and diversity in OS resulted from germination and growth of species adapted to the drawdown cycle of temporary ponds. Mud exposed after the pond dried was colonized rapidly, and at the time of sampling many of these plants had not yet set seed. When OS was visited 6 months later, the pond center was devoid of live above-ground vegetation (LaClaire unpubl. data). The plants had senesced and were ready to undergo rapid decomposition.

A comparison of species richness in BP and GP between the first and second vegetation sampling adds further insight. The number of species in the first sampling compared to the second sampling was 13 to 10 in BP and 15 to 17 in GP. There was a drop in diversity, as indicated by  $H'$ , for both ponds even though species richness for GP increased. The apparent discrepancy in  $H'$  for GP can be explained by comparing the average percent of live vegetation versus dead vegetation occurring in quadrats in the two different years. In 1989, live vegetation averaged 124% cover and dead vegetation averaged 31%. Greater than 100% cover in GP (1989) indicated the presence of layering in the quadrats, another important aspect of species diversity. In 1990, live vegetation decreased to 78% of the total cover and dead vegetation increased to 53%. Even though species richness increased, the total cover represented by these species decreased by almost 25%.

## CONCLUSIONS

### Composition and Structure of Temporary Pond Basin Vegetation

A total of 112 vascular plant species were identified in the study ponds. Of these, only *Panicum hemitomon* was found in every pond sampled. Though species composition of individual ponds tended to be dissimilar, the species represented components of a pattern of zonation that was consistent between ponds. Hydrology



determined the extent of zonation through direct and indirect effects on the composition of the wetland plant community. Each pond's position in its hydrologic cycle was reflected in its co-dominant species, species richness, and diversity. Species richness and diversity were highest in ponds which had dried-down less than one year previous to sampling and lowest in flooded ponds and ponds which had been dry for several years.

The high percentage of OBL in pond basins and the low WIV, in most cases, resulted from the presence of *Panicum hemitomon*. This species appears to have an important role in maintaining temporary pond basins, as exemplified by its presence in DP, which had been dry for over 7 years when sampled. Long-term persistence of *P. hemitomon* may reduce the rate of oxidation of organic matter, reduce soil moisture loss, and inhibit growth and establishment of upland adapted plant species.

### Conservation Implications

Because temporary pond vegetation is adapted to cycles of wet/dry, any one sampling of a pond will give only a small picture of the total community composition. This has important implications for the current dispute over wetland delineation. If wetland hydrology indicators were narrowed to exclude hydric soils and wetland vegetation as hydrology indicators, temporary ponds would not consistently meet the wetland criteria (USEPA 1991). However, wetland indicator values from this study, conducted during a period of drought, clearly identified the plant communities of all ponds studied as hydrophytic (Reed 1988; USEPA 1989).

Although most wetland plant species in temporary ponds senesce and die back, some of the most common plants are those most resistant to decomposition and may be useful in determining wetland boundaries (i.e. *Panicum hemitomon*, *Hypericum fasciculatum*, *Rhexia mariana*, and *Andropogon glomeratus*).

Data from this study could be used as a model to predict the temporary pond wetland type, occurring in uplands of north and north-central Florida, used for breeding by the Florida gopher frog and striped newt. The data also provide a foundation for the development of temporary pond management strategies. However, there are probably many other plant species present in these wetlands which were not identified by this study. Additional data collected during wet years, and tracked seasonally, would give a more complete picture of the plant community.

## LITERATURE CITED

- Grahamson, W. G., A. F. Johnson, J. N. Layne, and P. A. Peroni. 1984. Vegetation of the Archbold Biological Station, Florida: an example of the southern Lake Wales Ridge. *Florida Sci.* 47:209-250.
- Hotts, P. S., and B. C. Cowell. 1988. The distribution and abundance of herbaceous angiosperms in west-central Florida marshes. *Aquatic Bot.* 32:225-238.
- Jediges, E. L., and S. L. Orzell. 1989. Longleaf pine communities of the West Gulf Coastal Plain. *Nat. Areas J.* 9:246-261.
- Johnson, M. M., A. E. Lugo, and S. Brown. 1981. Primary productivity, decomposition, and consumer activity in freshwater wetlands. *Ann. Rev. Ecol. Syst.* 12:123-161.
- Cowell, A. F. 1985. Guide to the vascular plants of the Florida panhandle. Florida State Univ. Press, Tallahassee, USA.
- Orzell, J. J., and S. G. Fisher. 1979. Nutrient budgets of a temporary pond ecosystem. *Hydrobiologia* 63:213-222.
- Florida Natural Areas Inventory and Florida Department of Natural Resources. 1990. Guide to the natural communities of Florida. Florida Dept. Nat. Res., Tallahassee, USA.
- Ortiz, R., and D. W. Hall. 1991. Vegetative communities and annotated plant lists for the Katharine Ordway Preserve-Swisher Memorial Sanctuary, Putnam County, Florida. Ordway Preserve Research Ser., Rept. No. 3, Florida Mus. Nat. Hist., Gainesville, USA.
- Ortiz, R., and L. L. Smith. 1993. Distribution and status of the striped newt and Florida gopher frog in peninsular Florida. Final report submitted to Florida Game and Fresh Water Fish Comm., Nongame Wildl. Prog., Tallahassee, USA.
- Christensen, J., and H. S. Greening. 1989. Marsh seed banks of the Okefenokee Swamp: Effects of hydrologic regime and nutrients. *Ecology* 70:750-763.
- Orzell, B. 1986. Vegetation dynamics in temporary and shallow freshwater habitats. *Aquatic Bot.* 23:391-396.
- Gosselink, J. G., and R. E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems. Pp. 63-78 in R. E. Good, D. F. Whigham and R. L. Simpson (eds.). *Freshwater wetlands: Ecological processes and management potential*. Academic Press, New York, USA.
- Odum, J. P. 1979. Plant strategies and vegetation processes. John Wiley and Sons, New York, USA.
- Orzell, R. 1988. What about this vernal pool business? Pp. 351-355 in J. A. Kusler, S. Daly, and G. Brooks, eds. *Urban Wetlands: Proceedings of the National Wetland Symposium*. Omnipress, Madison, Wisconsin, USA.
- Ortiz, J. M. 1982. Pine flatwoods and seasonal ponds of southwest Florida: An illustrated guide. Senior Thesis, New College, Sarasota, Florida, USA.
- Ortiz, H. C., Jr., J. M. Post, Jr., M. Lopez, and R. G. Perry. 1989. Analysis of water level indicators in wetlands: Implications for the design of surface water management systems. Amer. Water Res. Assoc., Tech. Publ. Ser. TPS-89-3, Minneapolis, Minnesota, USA.
- Ortiz, J. A. 1990. Freshwater marshes. Pp. 324-363 in R. L. Myers and J. J. Ewel, eds. *Ecosystems of Florida*. Univ. Central Florida Press, Orlando, USA.
- Claire, L. V. 1992. The ecology of temporary ponds in north-central Florida. M. S. Thesis, Univ. Florida, Gainesville, USA.
- Claire, L. V., and R. Franz. 1991. Importance of isolated wetlands in upland landscapes. Pp. 9-15 in M. Kelly, ed. *Proc. 2nd Ann. Mtg., Florida Lake Mgmt. Soc., Winter Haven, Florida, USA*.
- Gosselink, A. M. 1942. The plant communities of the Welaka Area. *Univ. Florida Publ., Biol. Sci. Ser.* 4:1-143.
- Odum, E. E., and D. L. Jameson. 1964. Plant succession in temporary ponds at Willamette Valley, Oregon. *Amer. Midl. Nat.* 71:181-197.
- Orzell, E. F. 1986. The relationship between hydrology and vegetational pattern within the floodplain marsh of a subtropical, Florida lake. *Florida Sci.* 49:213-233.
- Ortiz, J. M., A. K. Gholson, Jr., and W. W. Baker. 1986. Natural Features Inventory of Ichauway Plantation, Georgia. Volume 2. Report prepared for Ichauway Plantation, Newton, Georgia and the Nature Conservancy, Southeast Regional office, Chapel Hill, North Carolina.
- Ortiz, D. B. 1990. Temporary ponds. *Florida Wildl.* 44:12-16.
- Ortiz, W. J., and J. G. Gosselink. 1986. *Wetlands*. Van Nostrand Reinhold, New York, USA.

- Moler, P. E., and R. Franz. 1987. Wildlife values of small, isolated wetlands in the southeastern coastal plain. Pp. 234-241 in R. R. Odom, K. A. Riddleberger, and J. C. Ozier, eds. Proc. 3rd Southeastern Nongame and Endangered Wildl. Symp., Georgia Dept. Nat. Res., Atlanta, USA.
- Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, USA.
- Patrick, W. H., Jr., and R. A. Khalid. 1974. Phosphate release and sorption by soils and sediments: Effect of aerobic and anaerobic conditions. *Science* 186:53-55.
- Puckett, C. 1982. Natural resources facilities and user policy and procedures at the Welaka Research and Education Center. Inst. Food Agric. Sci., Univ. Florida, Gainesville, USA.
- Readle, E. L. 1990. Soil survey of Putnam County Area, Florida. Natl. Coop. Soil Surv., U. S. Dept. Agric., Washington, D. C., USA.
- Reddy, K. R., T.C. Feijtel, and W. H. Patrick, Jr. 1986. Effect of soil redox conditions on microbial oxidation of organic matter. Pp. 117-148 in Y. Chen and Y. Avnimelech, eds. The role of organic matter in modern agriculture. Martinus Nijhoff Publishers, Boston, Massachusetts, USA.
- Reddy, K. R., and D. A. Graetz. 1988. Carbon and nitrogen dynamics in wetland soils. Pp. 307-318 in D. D. Hook, W. H. McKee, Jr., H. K. Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Jojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear, eds. The ecology and management of wetlands, volume 1: Ecology of wetlands. Timber Press, Portland, Oregon, USA.
- Reed, P. B., Jr. 1988. National list of plant species that occur in wetlands: national summary. U.S. Fish Wildl. Serv., Biol. Rept. 88(24).
- Shannon, C. E., and W. Weaver. 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana, USA.
- USDA (United States Department of Agriculture). 1984. Soils and vegetation of the Apalachicola National Forest. Forest Service, Southern Region, U. S. Dept. Agric., Washington, D.C., USA.
- USEPA (United States Environmental Protection Agency). 1989. Federal manual for identifying and delineating jurisdictional wetlands. Washington, D.C., USA.
- \_\_\_\_\_. 1991. Proposed revisions to the federal manual for delineating wetlands. U. S. Envir. Protec. Agcy., Washington, D.C., USA.
- van der Valk, A. G. 1981. Succession in wetlands: A Gleasonian approach. *Ecology* 62:688-696.
- van der Valk, A. G., and C. B. Davis. 1976. Changes in the composition, structure and production of plant communities along a perturbed wetland coenocline. *Vegetatio* 32:87-96.
- Weller, M. W. 1979. Wetland habitats. Pp. 210-234 in P. E. Greeson, J. R. Clark, and J. E. Clark, eds. Wetland functions and values: The state of our understanding. Amer. Water Res. Assoc., Minneapolis, Minnesota, USA.
- Wentworth, T. R., G. P. Johnson, and R. L. Kologiski. 1988. Designation of wetlands by weighted averages of vegetation data: a preliminary evaluation. *Water Res. Bull., Amer. Water Res. Assoc.* 24(2):389-396.
- Williams, D. D. 1987. The ecology of temporary waters. Timber Press, Portland, Oregon, USA.
- Wunderlin, R. R. 1982. Guide to the vascular plants of central Florida. Univ. Presses Florida, Tampa, USA.

# Movement Patterns and the Conservation of Amphibians Breeding in Small, Temporary Wetlands

C. KENNETH DODD, JR.\* AND BRIAN S. CADE†

\*Florida Caribbean Science Center, Biological Resources Division, U.S. Geological Survey, 7920 N.W. 71st Street, Gainesville, FL 32653, U.S.A., email kdodd@nervm.nerdc.ufl.edu

†Midcontinent Ecological Science Center, Biological Resources Division, U.S. Geological Survey, 4512 McMurry Avenue, Fort Collins, CO 80525, U.S.A.

**Abstract:** Many amphibians breed in water but live most of their lives in terrestrial habitats. Little is known, however, about the spatial distribution of these habitats or of the distances and directions amphibians move to reach breeding sites. The amphibian community at a small, temporary pond in northcentral Florida was monitored for 5 years. Based on captures and recaptures of more than 2500 striped newts (*Notophthalmus perstriatus*) and 5700 eastern narrow-mouthed toads (*Gastrophryne carolinensis*), we tabulated the angles of orientation that these amphibians entered and exited the pond basin. Our results showed that movements of these species between the pond and terrestrial habitats were nonrandom in orientation, but that narrow corridors did not appear to be used. Differences between the species likely reflect differences in habitat preferences, whereas intraspecific differences among years and between the sexes likely reflect variation among individuals. For terrestrial buffer zones to be effective at conserving pond-breeding amphibian communities, they need both a distance and a directional component. The determination of a directional component may be obscured if studies are carried out over a short time span. Conservation efforts for wetland-breeding amphibians that concentrate solely on the wetland likely will fail without consideration of the adjacent terrestrial habitat.

## Patrones de Movimiento y Conservación de Anfibios en Humedales de Temporal Pequeños

**Resumen:** Muchos anfibios se reproducen en el agua pero viven la mayor parte de sus vidas en hábitats terrestres. Sin embargo, poco se conoce sobre la distribución espacial de estos hábitats o de las distancias y direcciones en las que se mueven los anfibios para llegar a sus sitios de reproducción. La comunidad de anfibios en estanques temporales pequeños en Florida nor-central ha sido monitoreada por 5 años. En base a capturas y recapturas de más de 2500 tritones rayados (*Notophthalmus perstriatus*) y 5700 sapos de boca chica del este (*Gastrophryne carolinensis*), tabulamos los ángulos de orientación en que estos anfibios entraron y salieron de la cuenca del estanque. Nuestros resultados muestran que los movimientos de estas especies entre el estanque y los hábitats terrestres no tuvieron una orientación azarosa, pero los corredores angostos aparentemente no son utilizados. Diferencias entre las especies parecen reflejar diferencias en las preferencias de hábitat, mientras que diferencias intraespecíficas entre años y entre sexos parece reflejar variación entre individuos. Para que las zonas terrestres de amortiguamiento sean efectivas en la conservación de comunidades de reproductores de anfibios, necesitan tener como componentes una distancia y orientación. La determinación del componente direccional puede ser oscurecido si los estudios se llevan a cabo en un período de tiempo corto. Los esfuerzos conservacionistas para anfibios de reproducción en humedales tenderán a fallar si se concentran únicamente en el humedal sin tomar en consideración el hábitat terrestre adyacente.

## Introduction

Because of their diversity and abundance, amphibians are among the most important vertebrate components of wetland ecosystems. Populations can become quite large because amphibians are ectotherms and thus use energy for growth and reproduction rather than to maintain a constant body temperature (Pough 1983). The potentially large size of both adult and larval amphibian populations has important implications for both predators and prey and for community energy dynamics (Seale 1980; Taylor et al. 1988; Holomuzki et al. 1994; Blaustein et al. 1996). The effects that amphibian declines have on ecosystem structure are thus of concern to community ecologists as well as to conservation biologists (Beebee 1996).

Many amphibians have a typical biphasic life-history pattern. Adults migrate to breeding ponds, deposit eggs, and return to terrestrial habitats (Duellman & Trueb 1986). The eggs hatch as aquatic larvae that remain in the water for various amounts of time depending on hydroperiod, thermal regime, predation, competition, and other related factors (Pechmann et al. 1989; Newman 1992; Rowe & Dunson 1995; Skelly 1996). The larvae metamorphose and emigrate from the wetland toward terrestrial habitats. A few species have been reported to move in specific directions when entering or leaving a pond or small wetland, and it has been suggested that some species follow migratory corridors as they move to and away from breeding sites (Stenhouse 1985; Verrell 1987).

The southeastern coastal plain of the United States has experienced dramatic development and landscape changes during the last 100 years. Vast areas of forests have been cleared for agriculture, plantation forestry, and human occupation (Ware et al. 1993; Means 1996). For example, approximately 2% of the 33 million ha that once comprised the longleaf pine (*Pinus palustris*) forest on the southeastern coastal plain is extant, and less than 0.01% is in old-growth forest (Means & Grow 1985; Means 1996; Noss 1989). Temporary ponds and other semipermanent small wetlands scattered throughout the coastal plain disappeared as forests were cleared. Even now, the biological importance of small wetlands is underappreciated, and they are often ignored in wetland regulations (Hart & Newman 1995).

Temporary ponds serve as important breeding sites for many amphibians, and large numbers of species may be found in rather small ponds in the southeastern coastal plain. For example, 14 species of frogs were found breeding in temporary ponds in upland habitats in northcentral Florida (Moler & Franz 1987), 20 amphibians were found in a temporary pond on the coastal plain of Georgia (Cash 1994), 15 pond-breeding amphibians were captured at Breezeway Pond in northcentral Florida (Dodd 1992), and 16 species of amphibians were trapped from a series of nearby temporary

ponds in managed north Florida flatwoods (O'Neill 1995). A few amphibians of critical conservation concern (*Ambystoma cingulatum*, *Notophthalmus perstriatus*, *Rana capito*; Millsap et al. 1990) breed only in temporary ponds (Dodd 1995a, 1997). Small wetlands also are critical to the survival of many other invertebrate and vertebrate animal species (Dickinson 1949; Moler & Franz 1987; Gibbs 1993; Hart & Newman 1995).

From 1985 to 1990 the species richness and diversity of an amphibian community inhabiting a temporary pond in northcentral Florida was monitored (Dodd 1992). The sampling design used a nearly circular drift fence around the shallow pond basin. This design allowed us to re-examine the data collected during that study in order to determine whether the most commonly captured species were moving toward and away from the pond basin in a random or nonrandom fashion and to determine if certain directions were favored over others. Coupled with information on amphibian use of upland habitats (Dodd 1996), results of the analyses of movement patterns presented here could have important applications for both amphibian conservation and for the protection of small, temporary, wetland-dependent communities.

## Methods

### Study Site

Field data were collected from October 1985 to September 1990 at Breezeway Pond, a 0.16-ha temporary depression marsh (Florida Natural Areas Inventory 1990) located in a shallow 1.3-ha basin on the Katharine Ordway Preserve-Swisher Memorial Sanctuary, Putnam County, Florida (29°41'N, 82°00'W). The pond is located in xeric sandhill uplands near the ecotone between a longleaf pine, turkey oak (*Quercus laevis*), wiregrass (*Aristida beyrichiana*) community (termed "high pine" or sandhill) and a xeric oak (*Q. geminata* and *Q. hemisphaerica*) hammock community (Fig. 1). To the immediate south and west (at angles 72° to 298° from the pond basin's center), "high pine" sandhills predominate; to the north (at angles 299° to 360°, and 0° to 27°), xeric oak hammock predominates; to the northeast, a small grassland dominated by maidencane (*Panicum hemitomon*) is found at an angle of 28° to 71° from the center of the pond basin. The distance from the drift fence to the nearest forested plant association is generally 20 m but extends to about 50 m behind the *Panicum* meadow. Additional physical and vegetative details concerning the site have been presented by Dodd (1992, 1993) and LaClaire (1992). The pond held water continuously for 2 years prior to the study (R. Franz, personal communication).

The nearest water bodies to Breezeway Pond are Smith Lake (350 m north of Breezeway Pond) and three small

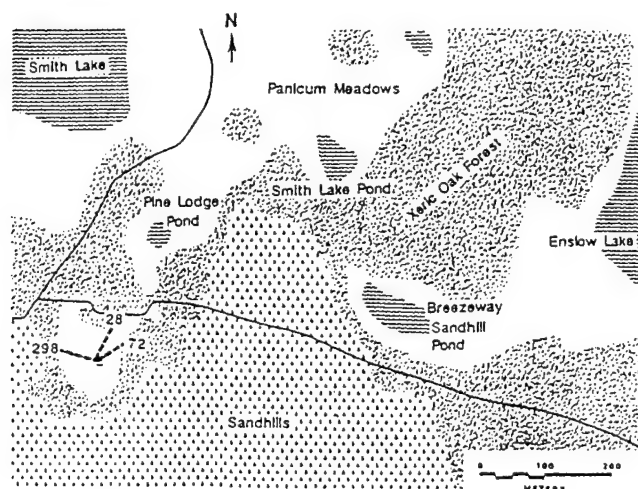


Figure 1. Breezeway Pond, Putnam County, Florida, in relation to adjacent habitat. The three dashed lines show the approximate angles between habitats immediately adjacent to Breezeway Pond. The solid lines are dirt roads.

temporary ponds, all located generally north or northeast of Breezeway Pond: Pine Lodge Pond (180 m distant), Smith Lake Pond (450 m distant), and Breezeway Sandhills Pond (400 m distant) (Fig. 1). Drought reduced Smith Lake—7.55 ha surface area in 1985—to approximately 0.75 ha in 1989; it completely disappeared on 29 May 1990. All temporary ponds dried completely in 1989 and remained dry through the remainder of the sampling period. This was approximately 1 year after the last standing water was recorded in Breezeway Pond.

### Species

Of the 16 species of amphibians captured at Breezeway Pond, the striped newt (*Notophthalmus perstriatus*) and the eastern narrow-mouthed toad (*Gastrophryne carolinensis*) were the most common. The striped newt (adults to 43-mm snout-vent length) is dependent on temporary wetlands for reproduction. Found from southern Georgia through central Florida and west to the Apalachicola National Forest in the central part of the Florida panhandle, it appears to be confined to the sandy uplands associated with former beach dunes and riverine terraces (Dodd & LaClaire 1995). Breeding occurs from late autumn to early spring, with larvae completing metamorphosis as ponds dry with the coming summer (Dodd 1993). As long as water is present, however, some larvae may remain through winter; neoteny is known at several locations. When not at ponds, striped newts live in terrestrial habitats that may be quite distant from the breeding pond (Dodd 1996). Striped newts appear to have evolved a rather plastic suite of life-history traits, which allows them to exploit

temporary breeding habitats that are available unpredictably both within and between years (Dodd 1993).

The eastern narrow-mouthed toad is a small (adults to 35-mm body length), secretive frog found throughout the southeastern United States. Unlike the habitat-specific striped newt, it breeds in a wide variety of temporary wetlands, including ponds, ditches and pools. In northern Florida, individuals may be found at any time of the year, although the majority of surface activity occurs from June through September during the breeding season (Dodd 1995b). Juveniles emigrate from ponds in the autumn and following spring during periods of rainfall (Dodd 1995b). Adults forage in the uplands, again often at considerable distance from the nearest pond (Dodd 1996), at the mouth of burrows made by vertebrates and invertebrates, and near surface debris offering refuge from heat and desiccation. Their diet consists almost entirely of ants.

### Sampling Procedure

The pond basin was enclosed by a 230-m drift fence made of galvanized metal flashing (36 cm above ground, 10–15 cm below the surface). Pitfalls (19-L black plastic buckets 36 cm deep) were placed on opposite sides of the fence at 10-m intervals (Gibbons & Semlitsch 1982). To minimize the effects of direct sun, the buckets were partially shaded (Dodd 1992). Coverboards were laid flat across the buckets when pitfalls were not checked in order to prevent desiccation; animals were captured even when the boards covered the bucket openings because the seals were not complete. The pitfalls were checked 5 days per week between 0700 and 0900 hours, depending on season, from October 1985 through September 1990 (1273 days; 83,950 bucket-nights).

Striped newts and eastern narrow-mouthed toads were examined in the field (for details and results see Dodd 1993, 1995b). Snout-vent length (SVL: tip of snout to posterior portion of vent of newts) and snout-urostyle length (SUL: tip of snout to the posterior end of the urostyle of frogs) were measured to the nearest millimeter with a clear plastic ruler.

The sex of adult striped newts was determined by the presence in males of a clearly visible, orange-colored gland cluster on the posterior portion of the vent that is present year-round. Females lacked this gland cluster and occasionally contained eggs. The sex of striped newts captured prior to mid-January 1986 was not determined. Animals smaller than 25 mm SVL were considered juveniles (Dodd 1993). Male eastern narrow-mouthed toads have a clearly visible black chin throat that varies in level of intensity year-round (Anderson 1954). In females the throat is mottled, light, and the same color as the venter (Wright 1932). Females occasionally contained eggs visible through the body wall. Animals smaller than 21 mm SUL generally were consid-



ered juveniles (Wright 1932; Anderson 1954), although the sex of some animals was difficult to determine at 22–24 mm SUL (Dodd 1995b). If the sex of an individual of either species was questionable, it was classified as an “unknown adult.”

Striped newts and eastern narrow-mouthed toads were marked by toe clipping following a year-specific cohort sequence; no more than one toe was clipped per foot. All captured animals were examined carefully for regenerated toes. After processing, individuals were released on the opposite side of the fence in such a manner as to minimize exposure to predators or extreme environmental conditions.

### Analysis of Orientation Data

A compass orientation was obtained by standing in the center of the pond basin and taking readings on the position of the 23 paired buckets at the drift fence. Rao's spacing test (Rao 1976; Batschelet 1981) was used to determine that animal captures were distributed uniformly on the circle of buckets because it has greater power to detect departures from uniform distributions for data with multiple modes and wide angular dispersion than Rayleigh's or Watson's  $U^2$  tests (Bergin 1991). Rao's spacing test was implemented as a special case of empirical coverage permutation tests (Mielke 1988). Analyses were run by sex (male, female) or life stage (juvenile) within each year and pooling across years for each species.

For within- and between-sex comparisons, we used a multiresponse permutation procedure (MRPP) for univariate grouped data that compares treatment groups analogous to a one-way analysis of variance. The permutation procedures, based on distance functions, allow test statistics to be based on powers of Euclidean distances. A variant of the MRPP for circular distributions, where the deviation between any two angles  $i$  and  $j$  is the minimum of  $|\text{angle}_i - \text{angle}_j|$  and  $360 - |\text{angle}_i - \text{angle}_j|$  (Mielke 1986), was used to compare distributions of animal captures between sexes, between immigrants and emigrants, and between years. The analyses were performed by means of a computer program (BLOSSOM) developed by the National Biological Survey (Slauson et al. 1991).

## Results

### Movement Patterns between Species

Striped newts and eastern narrow-mouthed toads both emigrated from and immigrated to Breezeway Pond in a nonrandom manner, regardless of sex, life stage, or year (Figs. 2 & 3). Except for juveniles, striped newts entered and exited from the pond basin in all directions. Fewer

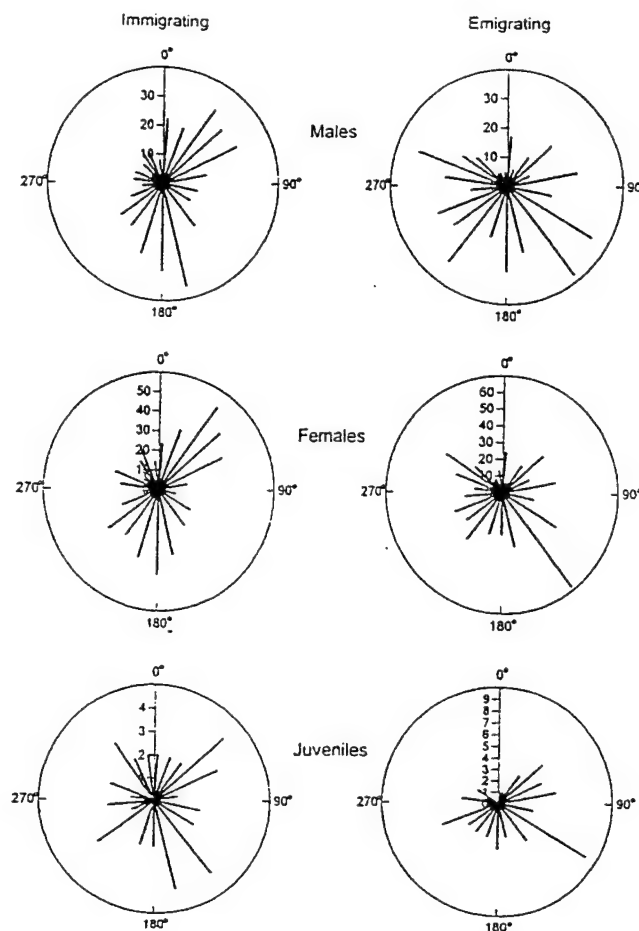


Figure 2. Patterns of immigration and emigration for striped newts (*Notophthalmus perstriatus*) at Breezeway Pond, 1985–1990. Orientations were not uniformly distributed on the circle (Rao's spacing test, all  $p < 0.01$ ). The length of the line based on the scale in each circle indicates the approximate number of animals moving to or from that direction.

adults were captured in buckets facing north and northwest than in buckets facing the other directions (Fig. 2), especially for immigrating and emigrating males and for emigrating females. Juveniles entered the pond primarily from the northwest through the southeast, but they appeared to avoid the northwest when emigrating (Fig. 2).

Adult eastern narrow-mouthed toads entered and exited the pond from all directions. Immigrating males entered the pond more from the northeast and southwest than they emigrated from the pond. Females had a similar pattern, although perhaps not as obvious (Fig. 3). With juveniles there were clear direction preferences. Two waves of juvenile movements were observed from 1985 to 1990. Successful reproduction occurred only once at Breezeway Pond, during the summer of 1985; a severe drought in northcentral Florida prevented successful reproduction during other years (Dodd 1995b).

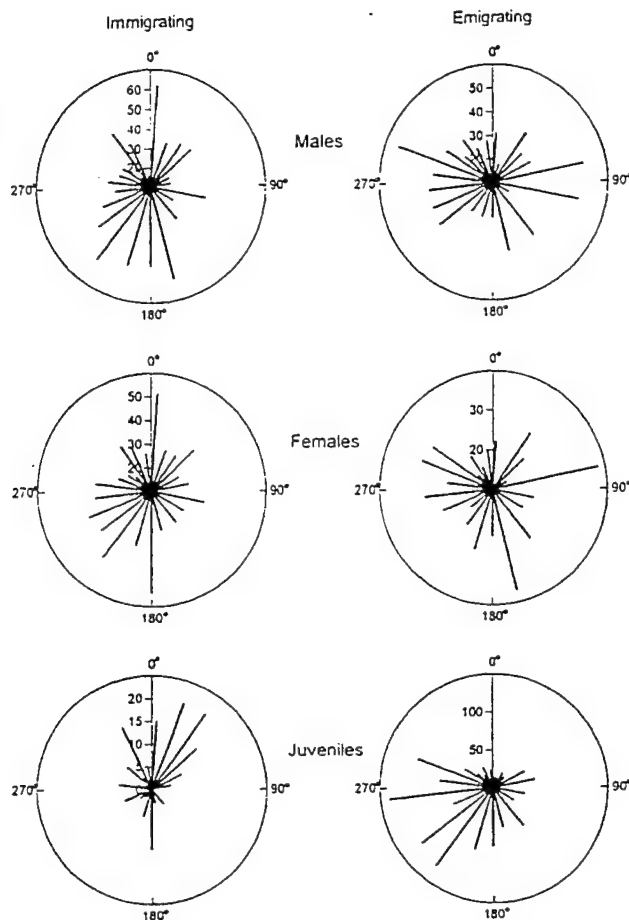


Figure 3. Patterns of immigration and emigration for eastern narrow-mouthed toads (*Gastrophryne carolinensis*) at Breezeway Pond, 1985-1990. The figures for juveniles show patterns only during the two peaks of movement: immigration from the fall of 1988 to the spring of 1989 and emigration from the fall of 1985 to the summer of 1986. Orientations were not uniformly distributed on the circle (Rao's spacing test, all  $p < 0.01$ ). The length of the line based on the scale in each circle indicates the approximate number of animals moving to or from that direction.

During the autumn of 1985 and spring of 1986, large numbers of juvenile *G. carolinensis* left the pond basin, primarily traveling toward the west, south, and south-southeast (Fig. 3). Juveniles immigrated to Breezeway Pond in numbers only from the autumn of 1988 to the spring of 1989 because drought caused distant Smith Lake and associated wetlands to dry completely (Dodd 1995b). These juveniles presumably were passing through the pond basin on their way to upland habitats (Dodd 1995b). Most juveniles entered Breezeway Pond from the north-northeast (Fig. 3), the location of the nearest temporary wetlands.

General trends of nonrandom movement may be somewhat misleading. Significant differences in move-

Table 1. Among-year comparison of the directional orientation of *Notophthalmus perstriatus* and *Gastrophryne carolinensis* entering and leaving Breezeway Pond, 1986-1990.

Comparison	Years	n	Standardized test statistic	p
<i>Notophthalmus perstriatus</i>				
Immigrating males	86-90	396	-4.5512	<0.001
Immigrating females	86-90	562	-0.9289	0.164
Emigrating males	86-89	433	-3.8581	0.003
Emigrating females	86-90	585	-4.5391	<0.001
<i>Gastrophryne carolinensis</i>				
Immigrating males	86-90	826	-2.3007	0.028
Immigrating females	86-90	737	-3.4494	0.005
Emigrating males	86-90	760	0.5046	0.651
Emigrating females	86-90	526	-2.4020	0.024

ment patterns were observed when emigration and immigration directions were examined among years (Table 1). The only exceptions were for immigrating female striped newts and for emigrating male eastern narrow-mouthed toads. Nonrandom movement to and from the ponds occurs regularly, but the directions change yearly and vary between the species.

#### Movement Patterns within Species

Male and female *N. perstriatus* did not show different emigration or immigration patterns at Breezeway Pond (Table 2). No significant differences were noted between the emigration and immigration patterns of juveniles (Table 2). Adult males, however, entered and left the pond basin in different ways, as did adult females. Both sexes emigrated more to the southeast and northwest than they immigrated to the pond from these directions.

As with striped newts, male and female *G. carolinensis* also did not show different immigration or emigration patterns between the sexes (Table 2). In contrast to *N. perstriatus*, male and female frogs entered and exited the pond basin to and from similar directions (Table 2). Juvenile eastern narrow-mouthed toads had significantly different patterns of immigration than of emigration (Table 2). They moved primarily toward the "high pine" habitats rather than toward the xeric oak hammock and *Panicum* meadow. Immigrating juvenile *G. carolinensis* entered the pond through the xeric oak hammock from the direction of the nearest water bodies.

To examine the directional orientation of these two species, we conducted within-year comparisons of directional orientation. Of the 42 possible comparisons (two species, two directions, two or three sex/life stages, 5 years; data were insufficient for many juvenile comparisons), only 4 comparisons were significantly different in any one year (Table 3).

In 1987 male and female striped newts emigrated and immigrated differently from each another: females generally entered the pond basin from the sandhills to the

Table 2. Overall comparison of the directional orientation of *Notophthalmus perstriatus* and *Gastrophryne carolinensis* entering and leaving Breezeway Pond, 1985–1990.

Comparison	n	Standardized test statistic	p
<i>Notophthalmus perstriatus</i>			
Immigrating vs. emigrating males	396, 435	-9.3190	<0.01
Immigrating vs. emigrating females	564, 585	-6.0922	<0.01
Immigrating vs. emigrating juveniles	46, 63	-0.5900	0.21
Immigrating males vs. females	396, 564	-0.4525	0.23
Emigrating males vs. females	435, 585	-0.3533	0.26
<i>Gastrophryne carolinensis</i>			
Immigrating vs. emigrating males	826, 760	-1.6796	0.07
Immigrating vs. emigrating females	737, 526	0.1727	0.44
Immigrating vs. emigrating juveniles*	159, 1267	68.6737	<0.01
Immigrating males vs. females	826, 737	0.2950	0.49
Emigrating males vs. females	760, 526	0.4371	0.57

\*Immigration only from fall 1988 to spring 1989; emigration only from fall 1985 to summer 1986.

southwest and west-northwest (angles 233° to 304°) in greater proportion than males, whereas males immigrated at a greater proportion than females at eight scattered locations around the perimeter of the pond (angles of 4°, 63°, 79°, 102°, 142°, 197°, 313°, and 352°). When emigrating, males left the pond at 13 angles in greater proportion than females, whereas females exited the pond basin at only three angles in greater proportion than males; neither sex showed any directionality. In 1989 male and female striped newts also immigrated differently, but the sample size was small ( $n = 64$ ) and spread out over 23 directions, making the determination of patterns impossible. However, only four females and one male entered the pond from the sandhills to the south-southwest and west (angles of 197° and 304°).

In 1988 male and female eastern narrow-mouthed toads emigrated differently. Males emigrated toward the west (angles 278° and 291°) in greater proportion than females, whereas females emigrated at seven angles proportionally more than males. Directionality was apparent (four of the seven angles grouped together) because females moved toward the high pine sandhills southeast and south-southwest of Breezeway Pond (at angles 121° to 197°).

## Discussion

Our data show that striped newts and eastern narrow-mouthed toads inhabiting the uplands of the Katharine Ordway Preserve do not move toward and away from breeding ponds randomly. Furthermore, neither species appears to use movement corridors, although the spacing of the pitfall buckets may cause some blurring of recorded directional tendencies. Emigrating animals may adjust their movement direction after they move away from the pond, whereas immigrating animals might be funneled in different directions as they contact the

fence. The placement of the drift fence likely did not influence migration because the patterns of emigration and immigration are rather broad, even accounting for displacement as animals traveled along the fence.

Movement patterns also changed somewhat from one year to the next. If corridors or scent trails were used in migration, the migratory pathways should be as precise as they are in certain other amphibians (Shoop 1965, 1968; Stenhouse 1985). For example, Shoop (1968) detected a travel corridor approximately 30 m wide for the salamander *Ambystoma maculatum* at a Massachusetts breeding pond. Although corridor use was not apparent by the species in our study, individual animals may follow the same pathways from one year to the next as they travel to the breeding pond. Stenhouse (1985) found that individual *A. maculatum* tended to enter and exit a pond at the same location from one year to the next, although for all animals taken together there was no specific directional tendency. Variation in movement patterns among individuals could account for the observed differences in orientation patterns among years in our study.

Table 3. Within-year comparison of the directional orientation of *Notophthalmus perstriatus* and *Gastrophryne carolinensis* entering and leaving Breezeway Pond, 1986–1990.<sup>a</sup>

Species <sup>b</sup>	Comparison	Year	n	Standardized test statistic	p
NP	Male vs. female	1987	452	-2.3851	0.033
	Emigrating				
NP	Male vs. female	1987	468	-4.2037	0.005
	Immigrating				
NP	Male vs. female	1989	64	-2.4078	0.034
	Immigrating				
GC	Male vs. female	1988	436	-3.2624	0.014
	Emigrating				

<sup>a</sup>Only significant differences are presented; all other comparisons within years were not significant at the  $p > 0.05$  level.

<sup>b</sup>NP, *Notophthalmus perstriatus*; GC, *Gastrophryne carolinensis*.

Although striped newts and eastern narrow-mouthed toads did not use narrow migratory corridors in our study, they did not move randomly between terrestrial habitats and breeding ponds. Certain directions were favored over others. Unlike in other studies that relate corridors to physical features of the local environment (Stein 1938; Hurlbert 1969; Healy 1975; Hershey & Forrester 1980), there are no obvious topographic cues surrounding Breezeway Pond to funnel migrating amphibians toward or away from the pond basin. Hence, it seems likely that the newts and frogs moved directly toward the pond from their nonbreeding habitats.

The declination at which individuals entered and left the pond basin is likely a reflection of the direction of favorable terrestrial habitats. In this regard, most striped newts favored high pine sandhill habitats, whereas eastern narrow-mouthed toads were likely to use a wider range of habitats. These results are consistent with previous observations of the ecology and biogeography of these species (Carr 1940; Dodd 1993, 1995b).

There are still many questions concerning the movements of these animals to ponds. For example, some amphibians, including the eastern narrow-mouthed toad (personal observation), do not breed every year. Hence, the number of animals at a pond represents only a fraction of the total population (Crump 1982). Perhaps the annual variation that we observed in orientation patterns, as well as the differences between the sexes, resulted solely from individual variation in propensity to move to a breeding site. The direction of immigration and emigration observed in any one year then would reflect that part of the population that bred in that particular year. General tendencies reflecting specific habitat preferences still would be apparent.

## Conservation Implications

Many amphibians use terrestrial sites at substantial distances from the nearest breeding ponds (Glandt 1986; Sinsch 1988; Denton & Beebe 1993; reviewed by Dodd 1996; Means et al. 1996). On the Katharine Ordway Preserve, striped newts have been found at distances up to 709 m, and eastern narrow-mouthed toads to 914 m from the nearest possible breeding pond (Dodd 1996). Unfortunately, we do not know what percentage of the total breeding population is found at various distances from the pond. Still, long-distance movements by amphibians to and from terrestrial habitats, sometimes occurring in specific directions from breeding sites, have important consequences for conserving wetlands and their dependent amphibian communities.

Most regulations affecting wetlands address the wetland itself or areas immediately adjacent to the wetland. Indeed, wetlands smaller than 0.2 ha (0.5 acre), such as Breezeway Pond, receive no protection in Florida (Hart

& Newman 1995). One partial solution to wetlands conservation is the requirement for terrestrial buffer zones around wetlands to reduce direct impacts. The width of buffer zones varies with the management objective involved. Even when terrestrial buffer zones are considered as part of regulations, as they are in some states (e.g., Massachusetts), they may be inadequate to protect wetland-breeding amphibian communities.

To our knowledge, very few studies have addressed the need for terrestrial buffer zones to protect wetland-dependent herpetofaunal communities. Burke and Gibbons (1995) pointed out the need for terrestrial buffer zones to protect aquatic turtle communities; they recommended a zone extending 275 m around an elliptical Carolina Bay to conserve 100% of nesting and hibernation sites. Smaller zones would protect proportionally smaller portions of required habitat, but even the most stringent state statute would protect only 44% of the critical terrestrial habitat. Brown et al. (1990) suggested only a 15-m buffer zone for "semi-aquatic reptile" nesting; for sandhill ponds, they recommended a buffer width of 223 m to ensure "high quality" habitat for wildlife around sandhill wetlands. Based on our results and data on distances amphibians move to breeding ponds (Dodd 1996), these recommendations are inadequate to protect sandhill amphibian communities.

No studies have empirically addressed the need for or size of buffer zones specifically for amphibian communities. Dubois (1991) suggested that a buffer zone 100–500 m alongside watercourses would protect a large portion of the amphibians using the site. Although Dodd (1996) trapped 83% of the amphibians captured incidentally to another study within 600 m of the nearest potential breeding source, sampling problems precluded a recommendation for exact buffer zone width.

Our results suggest that a directional component that takes amphibian habitat use into consideration should be evaluated when buffer zones surrounding wetlands are planned, especially isolated temporary wetlands. Drawing a regulatory circle around a pond (as in Brown et al. 1990) will not be sufficient to ensure amphibian community survival if certain species are preferentially using habitats at specific directions from the pond.

For terrestrial buffer zones to be effective at conserving pond-breeding amphibian communities, they need both a distance and a directional component. Managers will need to consider the many types of amphibian migratory patterns (Glandt 1986) and not just movements directly between a terrestrial home range and a breeding pond. Because of annual variation in individual movement patterns, the determination of the directional component may be obscured if studies are carried out over short time spans. It is imperative, therefore, that data be gathered on terrestrial habitat requirements during the nonbreeding times of the year.

Conservation efforts for amphibians that concentrate

solely on wetlands likely will fail without consideration of the adjacent terrestrial habitat. Although much media attention has focused on the unexplained loss of amphibian species and communities in many parts of the world (Wyman 1990; Blaustein & Wake 1995; Stebbins & Cohen 1995), the potential decline of even so-called common species due to landscape alteration of terrestrial habitats needs much further investigation.

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## Literature Cited

- Anderson, P. K. 1954. Studies in the ecology of the narrow-mouthed toad, *Microhyla carolinensis carolinensis*. Tulane Studies in Zoology 2:15-46.
- Batschelet, E. 1981. Circular statistics in biology. Academic Press, London.
- Beebe, T. J. C. 1996. Ecology and conservation of amphibians. Chapman & Hall, London.
- Bergin, T. M. 1991. A comparison of goodness-of-fit tests for analysis of nest orientation in Western Kingbirds (*Tyrannus Verticalis*). Condor 93:164-171.
- Blaustein, A. R., and D. B. Wake. 1995. The puzzle of declining amphibian populations. Scientific American 272(4):56-61.
- Blaustein, L., J. Friedman, and T. Fahima. 1996. Larval Salamandra drive temporary pool community dynamics: evidence from an artificial pool experiment. Oikos 76:392-402.
- Brown, M. T., J. M. Schaefer, and K. H. Brandt. 1990. Buffer zones for water, wetlands, and wildlife in east central Florida. Publication 89-07. Center for Wetlands, University of Florida, Gainesville.
- Burke, V. J., and J. W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina Bay. Conservation Biology 9:1365-1369.
- Carr, A. F., Jr. 1940. A contribution to the herpetology of Florida. Publication 3, Biological Science Series. University of Florida, Gainesville.
- Cash, W. B. 1994. Herpetofaunal diversity of a temporary wetland in the southeast Atlantic Coastal Plain. M.S. thesis. Georgia Southern University, Statesboro.
- Crump, M. L. 1982. Amphibian reproductive ecology on the community level. Pages 21-36 in N. J. Scott, editor. Herpetological communities. Wildlife research report 13. U.S. Fish and Wildlife Service, Washington, D.C.
- Denton, J. S., and T. J. C. Beebe. 1993. Summer and winter refugia of natterjacks (*Bufo calamita*) and common toads (*Bufo bufo*) in Britain. Herpetological Journal 3:90-94.
- Dickinson, J. C., Jr. 1949. An ecological reconnaissance of the biota of some ponds and ditches in northern Florida. Quarterly Journal of the Florida Academy of Science 11:1-28.
- Dodd, C. K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. Biodiversity and Conservation 1:125-142.
- Dodd, C. K., Jr. 1993. The cost of living in an unpredictable environment: the ecology of striped newts *Notophthalmus perstriatus* during a prolonged drought. Copeia 1993:605-614.
- Dodd, C. K., Jr. 1995a. Reptiles and amphibians in the endangered longleaf pine ecosystem. Pages 129-131 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources. National Biological Service, Washington, D.C.
- Dodd, C. K., Jr. 1995b. The ecology of a sandhills population of the eastern narrow-mouthed toad, *Gastrophryne carolinensis*, during a drought. Bulletin of the Florida Museum of Natural History 38:11-41.
- Dodd, C. K., Jr. 1996. Use of terrestrial habitats by amphibians in the sandhill uplands of north-central Florida. Alytes 14:42-52.
- Dodd, C. K., Jr. 1997. Imperiled amphibians: a historical perspective. Pages 159-196 in G.W. Benz and D.E. Collins, editors. Aquatic fauna in peril: the southeastern perspective. Special publication no. 1. Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, Georgia.
- Dodd, C. K., Jr., and L. V. LaClaire. 1995. Biogeography and status of the striped newt (*Notophthalmus perstriatus*) in Georgia, USA. Herpetological Natural History 3:37-46.
- Dubois, A. 1991. Les amphibiens des régions tropicales: facteurs de déclin et d'extinction. Cahiers d'Outre-Mer 42:393-398.
- Duellman, W. E., and L. Trueb. 1986. Biology of amphibians. McGraw Hill, New York.
- Florida Natural Areas Inventory. 1990. A guide to the natural communities of Florida. Florida Natural Areas Inventory and Florida Department of Natural Resources, Tallahassee.
- Gibbons, J. W., and R. D. Semlitsch. 1982. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. Brimelyana 7:1-16.
- Gibbs, J. P. 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13:25-31.
- Glandt, D. 1986. Die saisonalen Wanderungen der mitteleuropäischen Amphibien. Bonner Zoologische Beiträge 37:211-228.
- Hart, R., and J. R. Newman. 1995. The importance of isolated wetlands to fish and wildlife in Florida. Nongame wildlife program project report. Florida Game and Fresh Water Fish Commission, Tallahassee.
- Healy, W. R. 1975. Breeding and postlarval migrations of the red-spotted newt, *Notophthalmus viridescens*, in Massachusetts. Ecology 56:673-680.
- Hershey, J. L., and D. C. Forester. 1980. Sensory orientation in *Notophthalmus v. viridescens* (Amphibia: Salamandridae). Canadian Journal of Zoology 58:266-276.
- Holomuzki, J. R., J. P. Collins and P. E. Brunkow. 1994. Trophic control of fishless ponds by tiger salamander larvae. Oikos 71:55-64.
- Hurlbert, S. H. 1969. The breeding migrations and interhabitat wandering of the vermilion-spotted newt *Notophthalmus viridescens* (Rafinesque). Ecological Monographs 39:465-488.
- LaClaire, L. V. 1992. Ecology of temporary ponds in north-central Florida. M.S. thesis. University of Florida, Gainesville.
- Means, D. B. 1996. Longleaf pine forest, going, going... Pages 210-229 in M. B. Davies, editor. Eastern old-growth forests. Island Press, Washington, D.C.
- Means, D. B., and G. Grow. 1985. The endangered longleaf pine community. ENFO (Florida Conservation Foundation) September:1-12.
- Means, D. B., J. G. Palis, and M. Baggett. 1996. Effects of slash pine silviculture on a Florida population of flatwoods salamander. Conservation Biology 10:426-437.
- Mielke, P. W., Jr. 1986. Non-metric statistical analyses: some metric alternatives. Journal of Statistical Planning and Inference 13:377-387.
- Mielke, P. W., Jr. 1988. Goodness-of-fit and g-sample omnibus tests based on coverages. Pages 9-19 in J.N. Srivastava, editor. Probability and statistics: essays in honor of Franklin A. Graybill. Elsevier Science Publishers B.V., North Holland, New York.
- Millsap, B. A., J. A. Gore, D. E. Runde, and S. I. Cerulean. 1990. Setting



- priorities for the conservation of fish and wildlife species in Florida. Wildlife Monographs 111.
- Moler, P. E., and R. Franz. 1987. Wildlife values of small isolated wetlands in the southeastern coastal plain. Pages 234-241 in R. R. Odom, K. A. Riddleberger, and J. C. Ozier, editors. Proceedings of the third southeastern nongame and endangered wildlife symposium. Georgia Department of Natural Resources, Atlanta.
- Newman, R. A. 1992. Adaptive plasticity in amphibian metamorphosis. *Bioscience* 42:671-678.
- Noss, R. F. 1989. Longleaf pine and wiregrass: keystone components of an endangered ecosystem. *Natural Areas Journal* 9:211-213.
- O'Neill, E. D. 1995. Amphibian and reptile communities of temporary ponds in a managed pine flatwoods. M.S. thesis. University of Florida, Gainesville.
- Pechmann, J. H. K., D. E. Scott, J. W. Gibbons, and R. D. Semlitsch. 1989. Influence of wetland hydroperiod on diversity and abundance of metamorphosing juvenile amphibians. *Wetlands Ecology and Management* 1:3-11.
- Pough, F. H. 1983. Amphibians and reptiles as low-energy systems. Pages 141-188 in W. P. Aspey and S. I. Lustick, editors. *Behavioral energetics: the cost of survival in vertebrates*. Ohio State University Press, Columbus.
- Rao, J. S. 1976. Some tests based on arc-lengths for the circle. *Sankhya, Series B* 38:329-338.
- Rowe, C. L., and W. A. Dunson. 1995. Impacts of hydroperiod on growth and survival of larval amphibians in temporary ponds of central Pennsylvania, USA. *Oecologia* 102:397-403.
- Seale, D. B. 1980. Influence of amphibian larvae on primary production, nutrient flux, and competition in a pond ecosystem. *Ecology* 61:1531-1550.
- Shoop, C. R. 1965. Orientation of *Ambystoma maculatum*: movements to and from breeding ponds. *Science* 149:558-559.
- Shoop, C. R. 1968. Migratory orientation of *Ambystoma maculatum*: movements near breeding ponds and displacements of migrating individuals. *Biological Bulletin* 135:230-238.
- Sinsch, U. 1988. Seasonal changes in the migratory behaviour of the toad *Bufo bufo*: direction and magnitude of movements. *Oecologia* 76:390-398.
- Skelly, D. K. 1996. Pond drying, predators, and the distribution of *Pseudacris* tadpoles. *Copeia* 1996:599-605.
- Slauson, W. L., B. S. Cade, and J. D. Richards. 1991. User manual for BLOSSOM statistical software. Midcontinent Ecological Science Center, Biological Resources Division, U.S. Geological Survey, Fort Collins, Colorado.
- Stebbins, R. C., and N. W. Cohen. 1995. A natural history of amphibians. Princeton University Press, Princeton, New Jersey.
- Stein, K. F. 1938. Migration of *Triturus viridescens*. *Copeia* 1938:86-88.
- Stenhouse, S. L. 1985. Migration, orientation and homing in *Ambystoma maculatum*. *Copeia* 1985:631-637.
- Taylor, B. E., R. A. Estes, J. H. K. Pechmann, and R. D. Semlitsch. 1988. Trophic relations in a temporary pond: larval salamanders and their microinvertebrate prey. *Canadian Journal of Zoology* 66:2191-2198.
- Verrell, P. A. 1987. The directionality of migrations of amphibians to and from a pond in southern England, with particular reference to the smooth newt, *Triturus vulgaris*. *Amphibia-Reptilia* 8:93-100.
- Ware, S., C. Frost, and P. D. Doerr. 1993. Southern mixed hardwood forest: the former longleaf pine forest. Pages 447-493 in W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. *Biodiversity of the southeastern United States. Lowland terrestrial communities*. John Wiley & Sons, New York.
- Wright, A. H. 1932. Life-histories of the frogs of the Okefinokee Swamp, Georgia. Macmillan, New York.
- Wyman, R. L. 1990. What's happening to the amphibians? *Conservation Biology* 4:350-352.





# Citronelle Ponds: Little-Known Wetlands of the Central Gulf Coastal Plain, USA

George W. Folkerts

Department of Zoology and  
Wildlife Science

Auburn University

Auburn, Alabama 36949-5414 USA

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**ABSTRACT:** Citronelle ponds are forested depression wetlands occurring on relatively flat uneroded surfaces of the Citronelle Formation along the Gulf coast of the United States from Mississippi to the central Florida Panhandle. The depressions seem to have formed by the dissolution of kaolinite in the substrate and associated loss of volume. Most are temporarily flooded, typically from early winter to late spring. Soils are usually of the Grady series. Few depressions have connections with surface or subsurface drainage. Nearly all Citronelle ponds were forested in their primeval state, characteristically supporting pondcypress (*Taxodium ascendens* Brogn.) and swamp tupelo (*Nyssa biflora* [Walt.] Sarg.) as dominants. The fauna consists of species that can tolerate water fluctuation and frequent drying and includes a large diversity of crustaceans and insects. Fishes are seldom present. Most of the ponds are isolated amid lands used for agriculture and forestry. Few remain in anything resembling a natural state. Action to preserve representative Citronelle ponds is urgently needed.

*Index terms:* Citronelle ponds, depression wetlands, Gulf Coastal Plain, pondcypress temporary ponds

## INTRODUCTION

Depression wetlands of various kinds are widespread in the southeastern United States. The types that have been studied to varying extents include Carolina bays, cypress domes, wet prairies, sandhill ponds, interdune ponds, and a variety of other wet or moist depressions of karst or unknown origin. One rarely studied yet important type of depression wetland is so poorly known that most biologists in the Southeast are unaware of its existence. This type consists of ponds that lie on the surface of the Plio-Pleistocene Citronelle Formation in the western Florida Panhandle, southwestern Alabama, and southeastern Mississippi. These depression wetlands are distinct, in a number of ways, from superficially similar, previously described wetlands. Because of their association with the Citronelle Formation, they are hereinafter referred to as Citronelle ponds. Because these ponds are rapidly disappearing, and because they are not well known to biologists, a general description and natural history of these wetlands is provided here. I hope that presentation of this basic information will stimulate further and more intensive work in these natural habitats.

Examination of aerial photographs and topographic maps of portions of the region mentioned above reveals numerous depressions, many of which are filled with water, especially in the winter and spring

(Figures 1, 2, 3). Soil survey maps typically classify the soils as Grady series. As a result, soil scientists frequently call the ponds in the depressions "Grady ponds" (Cole and Dent 1964). Biologists have often adopted this term, but it is too broad to be satisfactory because it applies to ponds formed in a variety of ways having greatly differing biological characteristics. The name "Grady" was originally derived from a site in Grady County, Georgia, where the soil series of the same name was established in 1908. The type location for Grady soils was subsequently changed to Peach County and then to Miller County, Georgia. The present type location is a limesink pond in the Dougherty Plain region. At this site, the depression originated from collapse of underlying limestone of Miocene or Oligocene age. Apparently, Grady soils develop in a variety of types of wet depressions. Most of the limestone karst depression ponds on the eastern Gulf Coastal Plain are listed as possessing Grady soils in the various county soil surveys (e.g., Huckle and Weeks 1965, Middleton and Smith 1976, McNutt 1977). Wharton (1977) noted that Grady soils characterized both ponded upland sites and plugged limesinks. The name has been used for soils occurring in the area from Mississippi to Virginia.

Essentially no information exists on the biota or ecology of Citronelle ponds. Of the general works that have covered the aquatic and wetland habitat types in the

region in which Citronelle ponds occur (Glewwell 1981, O'Neil and Mettee 1982, McElroy et al. 1988, Brenner et al. 1990, Ewel 1990, Florida Natural Areas Inventory 1990, Crisman 1992), none mentioned these habitats in any specific way; most did not acknowledge their existence. The material that follows was accumulated over the period from 1973 to the present, with more intensive study and reconnaissance occurring since 1982. The intent is to provide general preliminary information on the biology and geology of these habitats in order to draw them to the attention of biologists and resource personnel. More intensive studies of a number of Citronelle pond wetlands are in progress, but only general information is presented here.

## ORIGINS

A variety of processes can produce depressions that retain water for periods of time sufficiently long to allow a wetland plant community to develop. In the southeastern United States, two of the most common depression types harboring wetlands are Carolina bays and limesinks. Carolina bays are elliptical depressions occurring on the Atlantic Coastal Plain from North Carolina (perhaps as far north as New Jersey) to extreme northern Florida (Sharitz and Gibbons 1982). The process through which Carolina bay depressions originated has never been determined with certainty, but it is likely that they either resulted from bolide impact or have an eolian origin of some type. Ross (1987) summarized the history of opinions on the

origin of these sites. It is unlikely that Citronelle ponds and Carolina bays have a common origin. Citronelle ponds are not usually elliptical. Although generally round or oval, they range in shape from elongate ovals and constricted ovals to very irregular. Citronelle ponds lack the uniform northwest-southeast orientation that typifies Carolina bays and lack the sandy ridge on the southeastern edge. The closest depression wetlands that have been called Carolina bays, in southcentral Georgia and adjacent Florida, are over 250 km from the nearest definite Citronelle ponds in Okaloosa County, Florida.

It is also unlikely that these depressions formed by karsting processes involving

limestone; that is, they have not formed as a result of the dissolution of subsurface bedrock. The region in which they occur has none of the features typical of limestone karst topography. The depressions and adjacent areas lack typical limesink morphometry in that the surrounding land does not slope toward the depressions. Rather, they occur on high, undissected, largely flat or gently undulating portions of the Citronelle Formation. Land around limestone solution dolines is characterized by a 30 to 40 degree slope (Jennings 1985). Citronelle ponds exist in landscapes without slope, as abrupt topographical depressions, often on some of the highest elevations in the vicinity (Figure 4). Furthermore, indications of established underground drainage in the area in which the ponds occur are nonexistent, and an integrated surface drainage system does exist. The fact that the underlying limestone is thickly mantled by the Citronelle Formation and Miocene undifferentiated strata, sometimes to a depth of 700 feet (Cagle and Newton 1963), also makes it seem unlikely that solution or collapse processes in limestone caused the depressions.

The highest concentrations of ponds tend to be in areas where the Citronelle formation is thickest—the reverse of what one would expect if collapse in underlying limestone strata had formed them. In addition, Citronelle ponds do not occur where surface drainages have eroded the Citronelle Formation. Depressions resulting from limestone karst phenomena would seemingly be more abundant in areas in which the mantle of strata overlying the limestone had been thinned by erosion. Cagle and Newton (1963) stated that the presence of these depressions "cannot be attributed to the solution of underlying limestone since limestone formations occur too deep to have influenced the topography." Palmquist et al. (1976) established that too thick a cover of material inhibited or reduced the genesis of dolines in Iowa. Nevertheless, in Wales, Thomas (1974) found more dolines in sandstone above limestone than in the exposed limestone itself. In Florida, Arrington and Lindquist (1987) found that dissolution of the Ocala limestone was responsible for depression

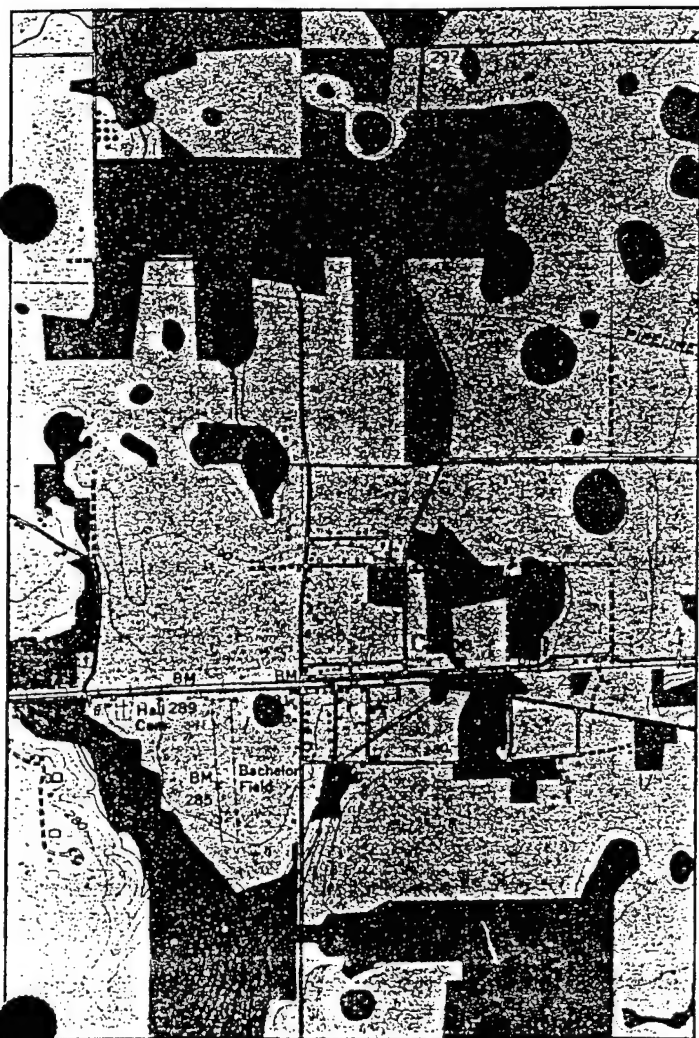


Figure 1. Portion of USGS 7.5-minute quadrangle map (Atmore) showing numerous Citronelle ponds, in Escambia County, Alabama. (Width of the map portion shown is 2.8 km.)

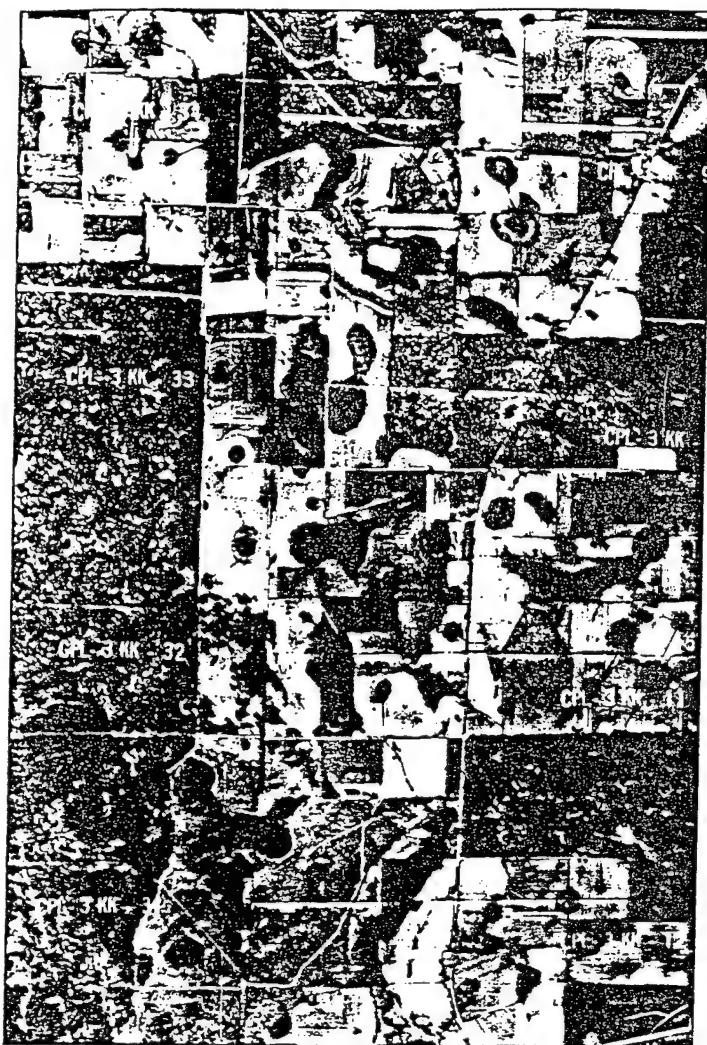


Figure 2. Aerial photograph mosaic showing an area of dense Citronelle ponds in eastern Escambia County, Alabama. Photos taken in 1968. (Width of the field of view is 4.8 km.)



Figure 3. Enlarged view of portion of Figure 2, revealing more detail. Large pondcypresses can be seen in the center of a number of the ponds. (Width of the field of view is 2.6 km.)

formation, even though the overlying sedimentary mantle was 35–130 m thick. Although perhaps possible, it seems unlikely that collapse of underlying limestone resulted in Citronelle pond depressions.

How did the depressions form? Otvos (1982) hypothesized that they were of "wind-blown" origin, but noted that some may have originated by faulting. In my opinion, eolian processes are unlikely to have formed the depressions, which lack the uniform orientation or shape that would be expected if ancient prevailing winds were involved. Conspicuous deposits of deflated materials are not found near the depressions, although transport and distri-

bution of the materials could have made them impossible to locate.

Recently, Ishfording and Flowers (1988) proposed that Citronelle depressions form by the dissolution of kaolinite in the substrate to form gibbsite. They contended that this process results in a volume loss of nearly 35%, causing settling of the soil. They found that depressions of this type are still forming, at least in Mobile County, Alabama, a fact further undermining a deflation hypothesis. Hunter (1989) claimed that the desilification involved in the conversion of kaolinite to gibbsite may not be capable of producing enough volume loss to account for the collapse. He suggested that at least part of the loss of

volume may be the result of dissolution of an iron oxide cementing material. This process was earlier proposed in a general way by Smith (1931) to explain the origin of the Carolina bays. In any event, a general hypothesis involving volume loss related to dissolution seems consistent with the topographical position and geological distribution of the depressions. There are a few depressions within the Citronelle pond area, such as one southeast of Huxford, Escambia County, Alabama, and several in the vicinity of Jay and Munson, Santa Rosa County, Florida, that have the morphometric appearance of limesinks. Deep auguring may be required to obtain a definitive answer to questions of formation.





Figure 4. A Citronelle pond, isolated by row-crop agriculture, on the flat surface of Citronelle Formation land (Escambia County, Alabama).

Dissolution of kaolinite and subsequent loss of volume was termed a "karst" process by Ishfording and Flowers (1988). They used the term in its broadest sense, a fashion usually promoted by Old World geologists. Biologists, apparently erroneously, often tend to restrict the terms, karst, karsting, and karst topography to processes and structures associated with limestone or related minerals. Biologists therefore may be inclined to avoid the use of "karst" for Citronelle ponds and associated processes. Regardless, it appears that the ponds should not be called "pseudo-karst" (Otvos 1976), as implied in the *National Atlas of the United States* (U.S. Geological Survey 1970).

#### DISTRIBUTION, ABUNDANCE, AND MORPHOMETRY

Citronelle ponds are often conspicuous features of landscapes in which they are abundant. In some portions of western Escambia County, Alabama, they occur in concentrations as high as  $10 \text{ km}^{-2}$  (Figures 1, 2, 3). If very small ponds or their remnants are counted, concentrations may be twice this great. Apparent density may be actual, such that pond distribution appears denser where relatively large uneroded portions of the Citronelle Formation remain. However, density also may

be related to the thickness of the formation, appearing to be greater in areas where the stratum is thickest. The depressions often appear clustered, although this also may be an artifact stemming from the discontinuous nature of undissected surfaces of the Citronelle Formation. Even so, large areas of Citronelle surface lack ponds or have only scattered ones.

As previously noted, almost all of the depressions lie on the undissected gently rolling or flat surfaces of the Citronelle Formation. A few seem to lie on erosion slopes adjacent to the uppermost surface, but these may be remnants of features modified by slope erosion rather than depressions that formed on slopes.

The ponds vary greatly in size. The largest occupy areas as large as 80–90 ha. Usually, ponds of this size have a multilobed shape, indicating that they may have formed by coalescence of a number of smaller depressions. The largest ponds lacking evidence of coalescence are around 20–30 ha in size. The smallest depressions that may be of this type are only 2–3 m in diameter and are detectable only by close examination of the surface. Not only have most of the very small ones been destroyed by agricultural or forestry activity, but because they are shallow, their vegetation tends to differ

little from surrounding sites, making them hard to detect. The smallest depressions clearly of the Citronelle Pond type are considerably less than 1 ha in size.

Although strata that have been referred to the Citronelle Formation, at least by some geologists, occur from Texas (Sellards et al. 1932) to the Carolinas (Soller and Mills 1991), the stratum varies greatly throughout this area. Otvos (1976) indicated that depressions in the Citronelle Formation occur only in an area between Harrison County, Mississippi, and Santa Rosa County, Florida. I have found depressions clearly of this type in a wider area, from Pearl River County, Mississippi, eastward to Okaloosa County in the central Florida Panhandle (Figure 5). In a very imprecise way, the distribution of the depressions described here coincides with the area of gibbsite-bearing soils developed on the Citronelle Formation as mapped by Clarke (1971) and by Ishfording and Flowers (1988). To the east of this area, although depressions are present in sandy, uneven Citronelle deposits, they are the result of collapse of underlying limestone (Otvos 1976). A few depressions, sometimes called flatwoods ponds, in other areas of the Southeast, such as in Liberty County, Florida, resemble Citronelle ponds. The "bagol" depressions of western Louisiana and eastern Texas (Holland et al. 1952, Bridges and Orzell 1989) may be Citronelle ponds or may have a similar origin. Clearly, depressions of this type may be more widespread than described here, but probably are not common in other areas.

Citronelle ponds occur in at least 13 counties, six in Mississippi, four in Alabama, and three in Florida (Figure 5). I am aware of at least 7,000 Citronelle pond depressions in these 13 counties. Baldwin County, Alabama, with more than 3,000, has the largest number. Citronelle ponds are most concentrated in eastern Baldwin County, Alabama, western Escambia County, Alabama, and northern Escambia and Santa Rosa Counties, Florida.

The Citronelle Formation slopes toward the south. The northernmost Citronelle ponds lie at elevations close to 120 m

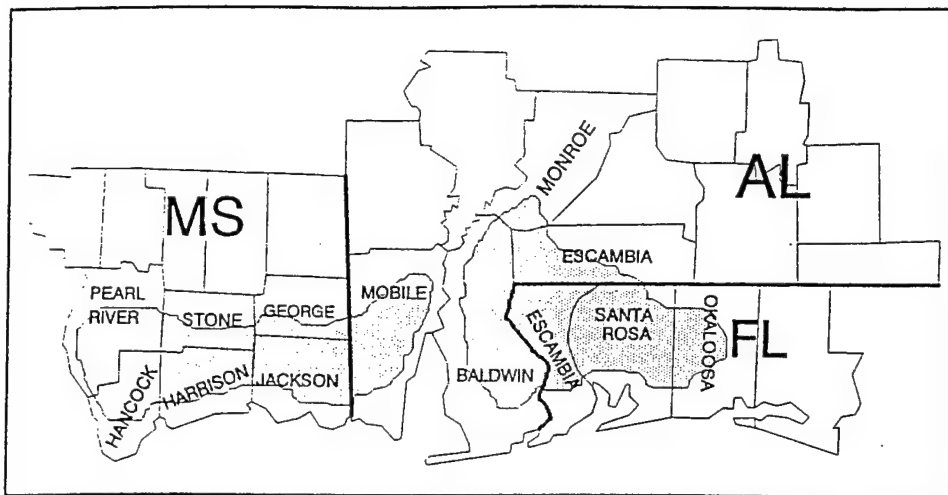


Figure 5. Map showing the known distribution of Citronelle ponds on the Lower Gulf Coastal Plain. Counties known to include ponds are named.

above sea level. The most southerly depressions are present on surfaces that lie at elevations of only 6 m.

Using county soil surveys, U.S. Geological Survey (USGS) topographic maps, aerial photographs, and ground surveys, I have determined the total area occupied by Citronelle pond depressions to be approximately 16,200 ha (ca. 40,000 acres). Baldwin County, Alabama, possesses the largest area, having about 4370 ha (ca. 10,800 acres) in ponds.

The depressions tend to be shallow with flat bottoms that slope very little toward the center; that is, most of the contour lines are crowded near the edge. They show little tendency to have conspicuously deeper areas near the center. At the edges, the gradual slope into the flat bottom begins rather abruptly in the surrounding level terrain of Citronelle lands.

## SOILS AND HYDROLOGY

County soil surveys indicate that nearly all of the Citronelle ponds in the western Florida Panhandle, southwestern Alabama, and southeastern Mississippi have Grady soils (Carlisle 1960, Cole and Dent 1964, Mattox 1975, Hickman and Owens 1980). However, soil type nomenclature has been inconsistent. There seems to be a decreasing tendency to use the Grady designation in more recent surveys. Other soil series listed for Citronelle ponds include Escam-

bia, Myatt, Portsmouth, and Rains. Most of these series seem to be typical Paleaquults. The soils are loamy, acid (pH 3.5–6.0), and generally developed on clay subsoils that inhibit downward percolation of ponded water. They are low in nutrients and in organic matter content (Hickman and Owens 1980).

Nearly all unaltered Citronelle depressions hold water in the winter and early spring. Rains tend to fill the ponds by mid-winter. Water levels tend to remain high until mid-April. Although variation exists, a general drying trend occurs from April until October, and many of the smaller ponds dry completely. No unaltered ponds observed have ever remained completely dry for more than a year. None of the ponds monitored since 1982 have ever frozen completely across the surface, although a thin film of ice has developed over portions of a few ponds during extremely cold periods.

Evapotranspiration seems to be a major factor in the hydrodynamics of the ponds during the warm portion of the year. It is not known whether or not percolation of water downward, as hypothesized for the process of pond formation, influences water levels. Even if the ponds become completely dry, a zone of saturation remains near the surface for much of the year. If the height of pondcypress (*Taxodium ascendens* Brogn.) knees can be used as a rough indication of mean maximum

water depth, the depth fluctuation in the largest ponds is at least 1.5 m.

Maximum depths at the deepest point at highest water periods can be from 1.2 to 1.8 m, as measured in 18 of the largest ponds. Water depth in Citronelle ponds is almost invariably related to pond area, larger ponds being deeper. All of the water in the ponds is derived from rain, including runoff from the very small catchment basin surrounding the ponds and interflow from adjacent saturated soils. Few of the ponds seem to have catchment areas much larger than twice the surface area of the pond itself, although hydraulic gradient is hard to gauge by eye and no surveying was done. USGS topographic maps show little or no slope toward the ponds from adjacent areas.

Few of the ponds are connected to surface drainage features. A small percentage lie at the edges of the flat uneroded surface of the Citronelle Formation and have developed outlets as they have been encroached upon by adjacent eroding declivities. An even smaller number seem to be part of very shallow surface drainage features that are only evident after heavy rains.

## BIOTA

The plants and animals typical of Citronelle ponds make up an assemblage generally similar to that of sinkhole ponds and cypress domes in southeastern North America (Sutter and Kral 1994). Species composition is clearly influenced by pond size and hydroperiod. The majority of the species found in Citronelle ponds, especially the animal species, are characteristic of temporarily or seasonally flooded wetlands and are absent from or rare in permanent waters in the area. Because the great majority of the sites have been altered and because all are to some degree surrounded by cropland or other artificial habitats, reconstruction of the primeval biotic composition is difficult. The information presented here comes from reconnaissance of several hundred ponds and from repeated visits to about thirty ponds in Escambia, Baldwin, and Mobile Counties, Alabama, and Escambia and Santa Rosa Counties, Florida.

## Vegetation

It seems almost certain that nearly all Citronelle ponds originally harbored a community dominated by pondcypress, swamp tupelo (*Nyssa biflora* [Walt.] Sarg.), or both. In the deepest areas of the larger ponds, only these two trees are present. In central areas where water depth is greater than 1 m at maximum depth, only pondcypress typically occurs (Figure 6). A small number of ponds examined contained only pondcypress; a smaller number were dominated by swamp tupelo and lacked pondcypress. These were always small ponds—most less than 1 ha in area. Whether these conditions were the result of anthropogenic factors could not be determined, but none of the very few ponds with a single dominant tree species evidenced a trace of the other species. Cypress was logged from most Citronelle ponds early in the twentieth century; some sites were harvested several times. However, logging seldom eliminates all traces of a species' former presence.

Local inhabitants refer to the sites as "cypress ponds" and claim that all originally had trees. Although treeless depression wetlands, such as fluctuating sandhill ponds and wet prairies, occur in southeastern North America (see Kushlan 1990), there is no strong evidence that any Citronelle ponds lacked trees in their original state. One pond north of Munson, Santa Rosa County, Florida, lacks all traces of trees and resembles sandhill ponds of the type that occur in limestone karst areas. A few ponds that lack pondcypress, tupelo, and other trees, are dominated by pond St. John's-wort (*Hypericum fasciculatum* Lam.) (Figure 7). Trees were probably removed from these sites early in this century, with no traces surviving to the present. Dispersal of propagules of wetland trees from one Citronelle pond to another probably occurs rarely.

The fact that Citronelle ponds nearly always contain trees is unusual. The annual hydrologic cycle, involving drying and filling in almost every year, may be a factor favoring colonization and reproduction by pondcypress and swamp tupelo. Fire could eliminate trees from a Citronelle pond, if



Figure 6. Interior of a Citronelle pond (Escambia County, Alabama). Pondcypress dominates the central portion, but swamp tupelo is abundant in shallower areas.



Figure 7. A Citronelle pond without trees (Escambia County, Alabama). Pond St. John's-wort (*Hypericum fasciculatum* Lam.) dominates. This aspect may have resulted from removal of trees.

the fire frequency was high and the fires hot. As far as can be determined, such conditions only rarely occur in the area. Further investigations of vegetation dynamics are needed.

The size of the dominant trees may vary greatly from one pond to another. It appears that both pondcypress and swamp tupelo become dwarfed owing to condi-

tions present in the shallower ponds. Alternatively, these could be ponds of recent origin and the trees may merely be young. At a number of sites where no evidence of logging exists, the pondcypress are all small in size. At other nearby sites, in larger, deeper ponds, the pondcypress are much larger, even though the sites may have been logged at least once. Ewel and Wickenheiser (1988), however, found no



significant differences in growth rates of pondcypress among ponds of different sizes in peninsular Florida.

Almost invariably, the understory in shallow edges is dominated by myrtle-leaved holly (*Ilex myrtifolia* Walt.). At a few sites, very large specimens of this species are present, in numbers greater than I have seen in other habitats. Slash pines (*Pinus elliotii* Engelm.) are often interspersed among the other trees in shallow peripheral areas. Other woody plants of shallower ponds or of peripheral areas of larger ponds include wax myrtle (*Myrica cerifera* L.), red maple (*Acer rubrum* L.), may haw (*Crataegus aestivalis*), pond St. John's-wort, Virginia willow (*Itea virginica* L.), sweet pepperbush (*Clethra alnifolia* L.), shining fetterbush (*Lyonia lucida* [Lam.] Koch.), and racemose fetterbush (*Leucothoe racemosa* [L.] Gray). Spanish moss (*Tillandsia usneoides* L.) drapes the trees in most of the ponds. Bamboo vine (*Smilax laurifolia* L.) is common; its congener, coral greenbrier (*Smilax walteri* Pursh), is frequent in shallow water. In contrast to the condition often found in cypress domes (Sutter and Kral 1994), especially in northern peninsular Florida, the understory vegetation in Citronelle ponds is never exceptionally dense.

Floating and stranded logs, the bases of pondcypresses, and stumps support a diverse flora, including representatives of nearly all of the woody species mentioned above. Sweet pepperbush and Virginia willow are especially common on pondcypress bases. Reddish bugleweed (*Lycopus rubellus* Moench) and Virginia marsh St. John's-wort (*Triadenum virginicum* [L.] Raf.) are very common on logs. In general, the flora of these microsites resembles that noted by Nixon et al. (1977). Similar epiligneous communities were studied by Norton and Gersbacher (1939), Hall and Penfound (1943), and Dennis and Batson (1975).

The amount and composition of the herbaceous vegetation vary from pond to pond. Shade from the dominant trees seems to be a factor in ponds in which little herbaceous vegetation is present. In the deepest areas of the larger ponds, only

submersed plants are present, but most of the larger ponds have at least some fragrant water lily (*Nymphaea odorata* Ait.) in the deeper areas. Radiate bladderwort (*Utricularia radiata* Small) is abundant in many ponds that have not been greatly disturbed. Relatively open shallow ponds and shallow open peripheral areas of larger ponds support Virginia chain fern (*Woodwardia virginica* J.E. Smith), sawgrass (*Cladium jamaicense* Crantz), spring pipewort (*Eriocaulon compressum* Lam.), yellow-eyed grasses (*Xyris* spp.), pink coreopsis (*Coreopsis nudata* Nutt.), and pine barren pond milkwort (*Polygala cymosa* Walt.).

It is difficult to hypothesize the composition of the original vegetation in areas immediately surrounding the depressions. There are few remnants of the vegetation indigenous to the flat surfaces of the Citronelle Formation. From the fragments present, it appears that areas immediately adjacent to the ponds consisted of moist deciduous forest dominated by diamond-leaf oak (*Quercus laurifolia* Michx.), water oak (*Quercus nigra* L.), sweetgum (*Liquidambar styraciflua* L.), and southern magnolia (*Magnolia grandiflora* L.). Flowering dogwood (*Cornus florida* L.) and American holly (*Ilex opaca* Ait.) may have been common understory components. Farther away from the ponds' influence on soil moisture, the vegetation was probably dominated by longleaf pine (*Pinus palustris* Mill.) and southern wiregrass (*Aristida beyrichiana* Trinius and Ruprecht).

Almost all of the ponds that still have trees show some evidence of past fires. Even trees in the central portions of the largest ponds often have fire scars or some remnants of charcoaling on the bark. Fire must have been very frequent in the surrounding pine-wiregrass habitats. The ponds themselves probably burned much less often, perhaps every 15–20 years, probably in association with droughty periods. Further investigation is necessary to determine the primeval fire frequency.

#### Invertebrates

Little is known about the invertebrate fauna of the ponds. Although many obvious-

ly possess a rich planktonic fauna, detailed studies are lacking. The information that follows is largely the result of my own observations.

The rhabdocoel turbellarian, *Dalyellia viridis* (Shaw), conspicuous because of its bright green color imparted by symbiotic chlorophytes, is common in many of the ponds in winter. During drying portions of the year, normally in the summer and fall, large populations of the naidid oligochaete *Dero vaga* (Leidy) are often present, especially in shallow marginal areas. These small worms, which construct cases composed of cladoceran ephippia and other substrate particles, have been found in concentrations as high as 20,000 m<sup>-2</sup>. Loden (1981) noted that this species, although present throughout the year, was most abundant in the fall in the southeastern United States.

A very diverse microcrustacean fauna develops in many of the ponds in early winter. Copepods, cladocerans, and ostracods are very abundant and apparently very diverse but no further information is available. Fairy shrimp of at least two species are abundant in many of the relatively undisturbed ponds during the winter and early spring. The most common and ubiquitous species is *Streptocephalus sealii* Ryder. Less common is a species of *Eubrachipus*. Dickinson (1948) reported members of both of these genera from temporary waters in northern peninsular Florida. Crayfish are abundant in some ponds but absent from others.

The aquatic insect fauna also appears to be diverse and is characteristic of fluctuating and temporary lotic sites along the Gulf coast. The odonate fauna apparently is very diverse, but only casual collecting has been done. Common species include the great blue skimmer (*Libellula vibrans* Fab.) and several spreadwings (*Lestes* spp.).

The whirligig beetle *Dineutus assimilis* Kirby is present in virtually every pond lacking major disturbance. A number of the ponds with shorter hydroperiods harbor populations of the crawling water beetle *Haliphus annulatus* Roberts, the only

southeastern member of the family typical of ephemeral waters. The characteristic pond acid fauna includes *Laccophilus proximus* Say and a number of species of *Agabus*, all typical of temporary sites.

Large numbers of water boatmen (Corixidae) leave residual pools in drying ponds in the fall, apparently overwintering in permanent waters in the area and flying into the ponds again in the spring. An unusual neuropteran, *Glenurus gratus* Say (Family Myrmeleontidae), has been encountered several times. The larval habitat of this species is in tree holes.

The acridid orthopteran *Metaleptea brevicornis* (Johannson) is abundant in ponds with graminoid vegetation. The pisaurid fishing spider *Dolomedes triton* (Walck.) is frequently encountered in ponds that support floating-leaved or emergent vegetation.

## Vertebrates

Fishes are absent from many of the ponds. This is apparently a result of the general lack of connections with surface drainage features and frequent drying. Residents of the area claim that, in the past, fishes were present in many of the ponds and gained access by areas of flow present only during heavy rains. Of the several hundred ponds examined, less than a dozen contained fishes. In several of these, the fishes, mainly centrarchids and ictalurids, had obviously been introduced. The presence of phyllopod crustaceans in many ponds indicates that fishes historically have been absent. The few ponds that seem to contain a native, non-introduced fish fauna often have only the mosquitofish, *Gambusia affinis* (B. and G.).

The temporary nature of the ponds seems predictive of high use by breeding amphibians, but fewer have been found than expected—probably a result of extensive disturbance of surrounding terrestrial sites. Among the anurans, southern cricket frog (*Acris gryllus* LeConte), green treefrog (*Hyla cinerea* Schneider), bull frog (*Rana catesbeiana* Shaw), and pig frog (*Rana grylio* Stejneger) are frequent. Many ponds harbor breeding aggregations of southern

chorus frog (*Pseudacris nigrita* LeConte) and spring peeper (*Pseudacris crucifer* Wied). Eastern narrow-mouthed toad (*Gastrophryne carolinensis* Holbrook) seldom occurs in unaltered ponds but is very common in sites from which most trees have been removed.

It is in the salamander fauna that I find Citronelle ponds surprisingly depauperate. A few sites harbor larvae of the spotted salamander (*Ambystoma maculatum* Shaw). Newts (*Notophthalmus viridescens* Raf.) were found in a few ponds. Dwarf salamanders (*Eurycea quadridigitata* Holbrook) may sometimes be found at the edges. Other salamanders known to inhabit similar sites on the Gulf Coastal Plain, but not yet found in Citronelle ponds, include the marbled salamander (*Ambystoma opacum* Gravenhorst), mole salamander (*Ambystoma talpoideum* Holbrook), tiger salamander (*Ambystoma tigrinum* Green), greater siren (*Siren lacertina* L.), and two-toed amphiuma (*Amphiuma means* Garden).

Although it is possible that further searching will reveal a diverse and abundant salamander fauna, the apparent general depauperacy of salamanders may be attributable to two factors. First, most of the ponds are surrounded by altered habitats, most of which have been converted to row-crop agriculture (Figure 4). Thus, much of the foraging habitat for the terrestrial adult stages has been destroyed. Second, the fact that many of the ponds often dry completely, and lack surface or subsurface connections with other water bodies, means that recolonization by forms such as sirens and amphiumas is precluded or greatly inhibited, if successful aestivation was impossible during the dry period.

The cottonmouth (*Agkistrodon piscivorus* Lac.) is the most frequently encountered aquatic snake but is not abundant at any sites. A few ponds support small populations of banded water snake (*Nerodia fasciata* L.). According to local residents, American alligator (*Alligator mississippiensis* Daudin) occurred in a number of the ponds earlier in the century. I know of only one site with indications of alligator

presence, although no alligators were sighted. Ponds without fishes could probably support small alligators only. Eastern mud turtle (*Kinosternon subrubrum* Lac.), common musk turtle (*Sternotherus odoratus* Latr.), and chicken turtle (*Deirochelys reticularia* Latr.) have been found in Citronelle ponds, but none of these are common or frequently encountered.

A large Citronelle pond in eastern Escambia County, Alabama, supports a nesting colony of wading birds—mainly cattle egrets (*Bubulcus ibis* L.) and a few little blue herons (*Egretta caerulea* L.). Wood ducks (*Aix sponsa* L.) are common on many of the larger wooded ponds, including some that are completely surrounded by agriculture.

## CONSERVATION STATUS AND FUTURE

The soils surrounding Citronelle depressions are relatively fertile fine sandy loams well suited for production of cotton, grains, legumes, and grasses. The level nature of the Citronelle Formation surface facilitates cultivation. Consequently, nearly all of the areas around the ponds have been cultivated at some time in the past. Much of the acreage continues to be used for row crops. Producing the area's major crops, corn (*Zea mays* L.), soybeans (*Glycine max* [L.] Merr.), and cotton (*Gossypium hirsutum* L.), typically involves intensive use of insecticides, herbicides, and fertilizers. When agrochemicals are applied aerially, they are bound to have effects on the ponds. Effects due to runoff of agrochemicals and their metabolites from adjacent fields may not be as cataclysmic as those observed in some other wetland types because Citronelle ponds have small catchment areas. The extent to which pond chemistry and biotic composition have been altered by these substances is not known.

Other wetland types in the vicinity, such as sinkhole ponds, river swamps, freshwater marshes, and pitcher plant bogs, are typically somewhat buffered from the effects of agriculture by soils or topography that are not conducive to intensive row-cropping, although many of these sites

have been grazed or converted to tree plantations. Hence, even though all depression wetlands have been degraded, Citronelle ponds may have suffered more than most as a result of their juxtaposition with areas converted to intensive uses.

The importance of small depression wetlands in the Southeast was only recently recognized. They are especially important for reptiles and amphibians that can tolerate, or in some cases require, highly variable hydroperiods (Moler and Franz 1988, LaClaire and Franz 1990, Dodd 1992). LaClaire (1992) remarked on the widespread disregard of the importance and uniqueness of temporary waters. Concerning Citronelle ponds specifically, their importance in the primeval environmental mosaic on surfaces of the Citronelle Formation can hardly be underestimated. Natural habitats of the Citronelle Formation, few remnants of which remain, are some of the most poorly studied and least protected in North America.

Unsound and short-sighted forestry practices pose a major threat to Citronelle ponds, as they do to most of the natural habitats of the Southeast. Many small ponds were obliterated by soil disturbance during clearcutting and were subsequently planted to pine. Of the larger ponds not surrounded by row-crop agriculture, the majority are surrounded by or adjacent to even-aged pine stands. Many were cleared during the harvest of surrounding upland trees. A few have been incorporated into sycamore (*Platanus occidentalis* L.) plantations. Development and use of moisture-tolerant strains of loblolly pine (*Pinus taeda* L.) bode ill for these communities and for many other wetland types in southeastern North America. Although pondcypress and swamp tupelo are still being removed from the ponds, these species grow too slowly to offer the quick returns desired by most landowners and commercial interests. Thus, further conversions to pine or other trees are likely.

Whether a pond is enveloped by tree plantations or agricultural fields, pond-to-pond dispersal, nutrient input, degree of shading, precipitation runoff, interflow, and numerous other factors are altered. It is unlikely that many of the natural features

of an isolated pond can survive for long with all surrounding land in anthropogenic habitats.

Cleared ponds seldom regain their original community composition, although a long successional process may eventually return them to a pondcypress-swamp tupelo community. They may develop a great variety of vegetation, depending on size and depth, original vegetation density, and degree of disturbance during clearing. Often, black willow (*Salix nigra* Marsh.) dominates, its anemochorous fruits facilitating colonization of isolated sites. Edges often become choked with common elderberry (*Sambucus canadensis* L.). In shallow open areas, water smartweeds (*Polygonum* spp.) may form dense stands. When soil disturbance has not been severe, the native woody understory and associated herbaceous elements may retain much of their integrity.

A number of exotic plant species occur in and around Citronelle ponds. Some of these are likely to alter the ecology of these sites significantly in the near future. Chinese privet (*Ligustrum sinense* Lour.) and Japanese honeysuckle (*Lonicera japonica* Thunb.) have invaded the edges of many of the sites. The latter is present on pondcypress bases in a number of ponds. Perhaps the greatest threat among the introduced plants is the Chinese tallow tree (*Sapium sebiferum* [L.] Roxb.), found in or around nearly 20% of the ponds. Since the early 1980s, this species has become conspicuous in many wetlands in the southeastern United States. Its habitat preferences seem roughly equivalent to that of red maple. At the edges of some Citronelle ponds it seems to be replacing the maple. A near total disregard for problems caused by exotic wetland and terrestrial plants has typified the actions of government resource and agriculture agencies. Consequently, rates and intensity of damage are likely to continue to increase.

The only introduced vertebrate conspicuous in the vicinity of Citronelle ponds is the armadillo (*Dasypus novemcinctus* L.). Trails of this species are often seen in peripheral areas of ponds. It is possible that armadillo foraging has had a signifi-

cant effect on the litter and surface fauna in these areas. Feral pigs (*Sus scropha* L.) occur in the vicinity but have not been seen in or around the ponds.

Irrigation tailwater presently represents a small threat to a number of these sites. However, the few ponds known to be receiving tailwater were already essentially destroyed by previous alterations. It is difficult to even provisionally assess the effects of many alterations, since neither baseline data nor current data are available on water chemistry, energy flow, or nutrient relationships within the ponds.

In my experience, regulatory agencies provide little or no protection for isolated temporary wetlands, especially if they are small in size. Even with statutory or regulatory protection, monitoring and enforcement are virtually impossible, or impractical, or they would overburden the limited numbers of agency personnel. Many Citronelle ponds continue to be destroyed or degraded. This is true of most other wetland habitats in the region.

There are no significant Citronelle pond areas in public ownership under conditions in which they are likely to be protected to any degree. Conecuh National Forest in southern Alabama and DeSoto National Forest in southern Mississippi may include a few representatives of these habitats, but no sites are definitely known. The northeastern portion of Eglin Air Force Base in Santa Rosa County, Florida, also may contain a small number of Citronelle ponds. Blackwater State Forest in the western Florida Panhandle contains a few sites that could be protected. The largest number and the highest densities of these ponds remain in private ownership, most in small landholdings, but there are a number on timber company lands.

If action is taken in the immediate future, it is possible that small areas containing groups of ponds can be saved from further degradation. Protection of single isolated ponds will be ineffective because isolation from other sites and lack of significant buffer areas will result in degradation of the ecosystem.

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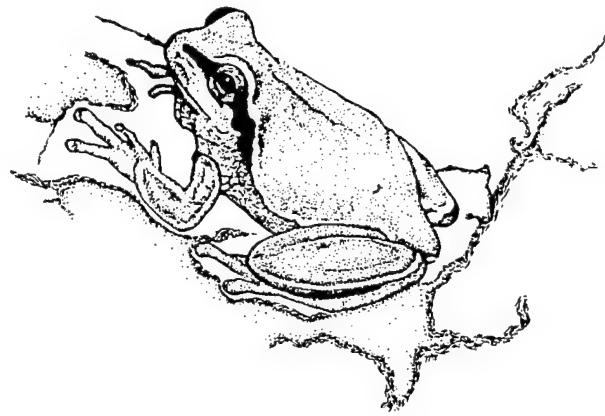
*George Folkerts teaches biology at Auburn University. He is interested in nature.*

## LITERATURE CITED

- Arrington, D.V. and R.C. Lindquist. 1987. Thickly mantled karst of the Interlachen, Florida area. Pp. 31-39 in B.F. Beck and W.L. Wilson, eds., *Karst Hydrogeology: Engineering and Environmental Applications*. Balkema, Boston, Mass.
- Brenner, M., M.W. Binford, and E.S. Deevey. 1990. Lakes. Pp. 364-391 in R.L. Myers and J.J. Ewel, eds., *Ecosystems of Florida*. University of Central Florida Press, Orlando.
- Bridges, E. L. and S.L. Orzell. 1989. Longleaf pine communities of the west Gulf Coastal Plain. *Natural Areas Journal* 9:246-263.
- Cagle, J.W., Jr., and J.G. Newton. 1963. Geology and ground-water resources of Escambia County, Alabama. Alabama Geological Survey Bulletin 74. 205 p.
- Carlisle, V. W. 1960. Soil survey of Escambia County, Florida. U.S. Department of Agriculture, Soil Conservation Service.
- Clarke, O.M. 1971. Gibbsite in coastal plain soils, southeastern United States. *Southeastern Geology* 13:77-90.
- Clewell, A.F. 1981. Natural setting and vegetation of the Florida Panhandle. Report prepared under contract No. DACWO1-77-C-0104 from the U. S. Army Corps of Engineers, Mobile, Ala.
- Cole, W.A. and J.H. Dent. 1964. Soil survey of Jackson County, Mississippi. U.S. Department of Agriculture, Soil Conservation Service.
- Crisman, T.L. 1992. Natural lakes of the southeastern United States: origin, structure, and function. Pp. 475-538 in C.T. Hackney, S.M. Adams, and W.H. Martin, eds., *Biodiversity of the Southeastern United States*. John Wiley and Sons, New York.
- Dickinson, J.C., Jr. 1948. An ecological reconnaissance of the biota of some ponds and ditches in northern Florida. *Quarterly Journal of the Florida Academy of Sciences* 11:1-28.
- Dodd, C. K. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. *Biodiversity and Conservation* 1:125-142.
- Ewel, K. C. 1990. Swamps. p. 281-322 in R.L. Myers and J.J. Ewel, eds., *Ecosystems of Florida*. University of Central Florida Press, Orlando.
- Ewel, K.C. and L.P. Wickenheiser. 1988. Effect of swamp size on growth rates of cypress (*Taxodium distichum*) trees. *American Midland Naturalist* 120:362-370.
- Florida Natural Areas Inventory. 1990. Guide to the natural communities of Florida. Florida Department of Natural Resources, Tallahassee.
- Hickman, G.L. and C. Owens. 1980. Soil survey of Mobile County, Alabama. U.S. Department of Agriculture, Soil Conservation Service.
- Holland, W.C., L.W. Hough, and G.E. Murray. 1952. Geology of Beauregard and Allen parishes, Louisiana. Geological Bulletin 27, Louisiana Geological Survey.
- Huckle, H.F. and H.H. Weeks. 1965. Soil survey of Washington County, Florida. U.S. Department of Agriculture, Soil Conservation Service.
- Hunter, D. 1989. Karst development in coastal plain sands: a "new" problem in foundation engineering. Discussion. *Bulletin of the Association of Engineering Geologists* 26:397-401.
- Ishfording, W.C. and G.C. Flowers. 1988. Karst development in coastal plain sands: a "new" problem in foundation engineering. *Bulletin of the Association of Engineering Geologists* 25:95-104.
- Jennings, J.N. 1985. Karst Geomorphology. Basil Blackwell, Oxford, England.
- Kushlan, J. A. 1990. Freshwater marshes. Pp. 324-363 in R.L. Myers and J.J. Ewel, eds., *Ecosystems of Florida*. University of Central Florida Press, Orlando.
- LaClaire, L.V. 1992. Ecology of temporary ponds in north-central Florida. Masters thesis, University of Florida, Gainesville.
- LaClaire, L.V. and R. Franz. 1990. Importance of isolated wetlands in upland landscapes. Pp. 9-15 in M. Kelly, ed., *Florida Lake Management Society, Proceedings of the 2nd Annual Meeting*, Winter Haven.
- Loden, M.S. 1981. Reproductive ecology of Naididae (Oligochaeta). *Hydrobiologia* 83:115-123.
- Mattox, M.G. 1975. Soil survey of Escambia County, Alabama. U.S. Department of Agriculture, Soil Conservation Service.
- McNutt, R.B. 1977. Soil survey of Geneva County, Alabama. U.S. Department of Agriculture, Soil Conservation Service.
- Middleton, R.G. and E.H. Smith. 1976. Soil survey of Miller and Seminole counties, Georgia. U.S. Department of Agriculture, Soil Conservation Service.
- Moler, P.E. and R. Franz. 1988. Wildlife values of small, isolated wetlands in the Southeastern Coastal Plain. Pp. 234-241 in R.R. Odom, K.A. Riddleberger, and J.C. Dozier, eds., *Proceedings of the Third Nongame and Endangered Wildlife Symposium*, Georgia Department of Natural Resources, Social Circle.
- Nixon, E.S., W.F. Trotty, B.L. Bates, and D.L. Wilkinson. 1977. Analysis of stump vegetation in an east Texas pond. *The Texas Journal of Science* 28:366-367.
- Norton, E.M. and E.O. Gersbacher. 1939. Stump vegetation in Reelfoot Lake. *Journal of the Tennessee Academy of Sciences* 14(1):181-185.
- O'Neil, P.E. and M.F. Mettee. 1982. Alabama coastal region ecological characterization. Vol. 2. A synthesis of environmental data. FWS/OBS-82/42, U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.
- Otvos, E.G. 1976. "Pseudokarst" and "pseudokarst terrains": problems of terminology. *Geological Society of America Bulletin* 87:1021-1027.
- Otvos, E.G. 1982. Coastal geology of Mississippi, Alabama, and adjacent Louisiana areas. New Orleans Geological Society, New Orleans, La.
- Palmquist, R., G.A. Madenford, and J.N. Vandrill. 1976. Doline densities in northeastern Iowa. *Bulletin of the National Speleological Society* 38:59-67.
- Ross, T.E. 1987. A comprehensive bibliography of the Carolina bays literature. *The Journal of the Elisha Mitchell Scientific Society* 103:28-42.
- Sellards, E.H., W.S. Adkins, and F.B. Plummer. 1932. *The Geology of Texas*. University of Texas, Austin.

- Sharitz, R.R. and J.W. Gibbons. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. FWS/OBS-82/04, U.S. Fish and Wildlife Service, Division of Biological Services, Washington, D.C.
- Smith, L.L. 1931. Solution depressions in sandy coastal sediments of the coastal plain in South Carolina. *Journal of Geology* 39:641-653.
- Soller, D.R. and H.H. Mills. 1991. Surficial geology and geomorphology. Pp. 290-308 in J.W. Horton, Jr., and V.A. Zullo, eds., *The Geology of the Carolinas*. The University of Tennessee Press, Knoxville.
- Sutter, R.D. and R. Kral. 1994. The ecology, status, and conservation of two non-alluvial wetlands communities in the South Atlantic and Eastern Gulf Coastal Plain, USA. *Biological Conservation* 68:235-243.
- Thomas, T.M. 1974. The South Wales interstratal karst. *Transactions of the British Cave Research Association* 1:131-152.
- U.S. Geological Survey. 1970. *The National Atlas of the United States*. U.S. Geological Survey, Washington, D.C.
- Wharton, C. H. 1977. *The natural environments of Georgia*. Georgia Department of Natural Resources, Atlanta.
- Wolfe, S.H., J.A. Reidenauer, and D.B. Means. 1988. An ecological characterization of the Florida Panhandle. *Biological Report* 88(12), U.S. Fish and Wildlife Service, Minerals Management Service OCS Study/MMS 88-0063, Washington, D.C.





# Amphibians in Peril: Resource Management in the Southeast

Linda V. LaClaire

In this chapter I will review past and current resource management programs that have benefited amphibians in the southeastern United States and management strategies that could be used to conserve the Southeast's imperiled amphibian fauna. Many of the projects and concepts discussed here are relatively new and much of the information provided was obtained from the "gray" literature (e.g., various federal, state or private agency reports) or from unpublished data. Nonetheless, this information provides a significant foundation upon which to build the consensus needed to ensure that the modest strides made in amphibian management will continue. Conservation of our imperiled amphibian fauna will require a commitment from resource managers to include amphibians in management planning at local, regional, national, and global levels.

Amphibian life histories grade from those that are totally aquatic to those that are entirely terrestrial; however, all amphibian species require a moist environment. Management efforts needed to protect the watersheds and wetlands inhabited by aquatic amphibians are often the same ones required to protect the moist woodland environments that are home to many terrestrial amphibians. Moreover, because water quality in wetlands is often dependent on conditions prevailing in surrounding terrestrial habitats, and because many amphibians depend on both aquatic and terrestrial habitats, the management of aquatic and terrestrial habitats can seldom be separated from one another when considering conservation measures aimed at amphibian resources. It is for this reason that this chapter will consider all imperiled amphibians in the southeastern United States, no matter what their degree of connection to aquatic habitats. The southeastern United States is



defined as the region composed by the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee.

In this chapter, management is considered in broad terms as those techniques and activities which strive to maintain the continuity of ecological and evolutionary processes (O'Connell and Noss, 1992). Because habitat loss is the primary threat to imperiled amphibians in the Southeast, the development of effective habitat management plans is crucial for amphibian conservation. Unfortunately, few management projects have been specifically directed at amphibian species or populations in the Southeast or elsewhere throughout the United States.

Most amphibian management has involved species listed under the Endangered Species Act or those species listed by individual states. Priorities determining the allocation of management resources are often based on these federal and state lists (Master, 1991). In the past, the federal candidate species list (U.S. Fish and Wildlife Service, 1994b) was used to identify species that may be biologically vulnerable and in need of active management. However, the U.S. Fish and Wildlife Service (1996) has revised its list of candidate taxa to include only those species which have been proposed for listing or which were previously considered Category 1 candidates. Category 1 candidates were those species for which sufficient data were available to support a proposed rule, but issuance of the rule was precluded by other listing activity. Category 2 candidates, those species which were being assessed for biological vulnerability and threat, are no longer included on the candidate list; these taxa are considered species of concern. Another prioritization system has been developed by The Nature Conservancy (TNC) in cooperation with the Natural Heritage Data Center Network (NHDCN) (NHDCN, 1993). Numeric ranks given for species with potential global biological vulnerability include: G1 = critically imperiled; G2 = imperiled; G3 = rare or uncommon; and G4 = widespread, abundant, and apparently secure, but with cause for long-term concern. This system has been used to develop lists of species with ranked levels of imperilment (TNC and the International Network of Natural Heritage Programs and Conservation Data Centers, 1996).

In the following discussion I will consider "imperiled" amphibians of the Southeast to be those species which are listed under the Endangered Species Act or by a state management agency, former federal Category 2 candidate species, and G1-G3 TNC/NHDCN ranked species (see Table 1). While extensive data are not available to support declines in all of these species, there is general concern among biologists that without effective management these amphibians will truly be in peril.

Under the Endangered Species Act, only one southeastern amphibian is listed, the Red Hills salamander (*Phaeognathus hubrichti*) (U.S. Fish and Wildlife Service, 1994a). An additional 15 amphibian species (12 salamanders and three frogs) were formerly considered federal Category 2 candidates (U.S. Fish and Wildlife Service, 1994b). Six of the ten states in the Southeast (Florida, Georgia, Mississippi, North Carolina, South Carolina, and Tennessee) have lists of state protected amphibian species. Twenty-six salamanders and six frogs are on these lists. The current list compiled by TNC and the Natural Heritage Program ranks 20 salamanders and two frogs as critically imperiled, imperiled, or rare and uncommon. There is considerable overlap between these lists, as many species appear on more than one list (see Table 1). Counting each species only once, the total number of imperiled amphibians equals 46, including 39 salamanders and seven frogs (see Table 2). The total number of native amphibian species known to occur in the South-

Table 1. Imperiled amphibian fauna of the southeastern United States.<sup>1</sup> This list contains amphibians listed under the Endangered Species Act and other species of concern (former Category 2 candidate species), as well as those listed by a state, or ranked as G1-G3 by The Nature Conservancy and Natural Heritage Programs (TNC). STATE LIST CATEGORIES: WM = wildlife in need of management; R = rare; SC = species of special concern; T = threatened; E = endangered; NL = not listed; - = not resident in state. FEDERAL RANK: SC = species of concern (former Category 2 candidate species); T = threatened; NR = not ranked. TNC RANK: G3 = rare or uncommon; G2 = imperiled; G1 = critically imperiled; Q = taxonomy questioned; ? = ranking inexact; ? = ranking inexact; ? = ranking inexact.

Amphibian Taxa	State Lists										Federal Rank	TNC Rank
	AL	AR	FL	GA	KY	LA	MS	NC	SC	TN		
SALAMANDERS												
Cryptobranchidae												
<i>Cryptobranchus alleganiensis</i> (eastern hellbender)	NL	NL	-	R	NL	-	NL	SC	NL	WM	SC	G3 <sup>2</sup>
Protidae												
<i>Necturus</i> sp. (Black Warrior waterdog)	NL	-	-	-	-	-	-	-	-	-	SC	G2
<i>N. lewisi</i> (Neuse River waterdog)	-	-	-	-	-	-	-	SC	-	-	NR	G3
<i>N. maculosus</i> (mudpuppy)	NL	-	-	NL	NL	NL	NL	SC	-	NL	NR	NR
Amphiumidae												
<i>Amphiuma pholeter</i> (one-toed amphiuma)	NL	-	NL	R	-	-	-	-	-	-	NR	G3
Sirenidae												
<i>Pseudobranchius striatus belli</i> (Everglades dwarf siren)	-	-	NL	-	-	-	-	-	-	-	NR	G3?
<i>P. s. lustricolus</i> (Gulf hammock dwarf siren)	-	-	NL	-	-	-	-	-	-	-	SC	NR
<i>P. s. spheniscus</i> (slender dwarf siren)	-	-	NL	NL	-	-	-	-	-	-	NR	G3?
<i>P. s. striatus</i> (broad-striped dwarf siren)	-	-	NL	NL	-	-	-	-	T	-	NR	G3?

Table 1. Continued.

Amphibian Taxa	State Lists										Federal Rank	TNC Rank
	AL	AR	FL	GA	KY	LA	MS	NC	SC	TN		
<b>Ambystomatidae</b>												
<i>Ambystoma cingulatum</i> (flatwoods salamander)	NL	-	NL	R	-	-	-	-	E	-	SC	G2/G3
<i>A. talpoideum</i> (mole salamander)	NL	NL	NL	NL	NL	NL	NL	SC	NL	WM	NR	NR
<i>A. tigrinum tigrinum</i> (eastern tiger salamander)	NL	NL	NL	NL	NL	NL	NL	T	NL	NL	NR	NR
<b>Salamandridae</b>												
<i>Notophthalmus perstriatus</i> (striped newt)	-	-	NL	R	-	-	-	-	-	-	SC	G2/G3
<b>Plethodontidae</b>												
<b>Desmognathinae</b>												
<i>Desmognathus aeneus</i> (seepage salamander)	NL	-	-	NL	-	-	-	NL	-	NL	SC	NR
<i>D. apalachicola</i> (Apalachicola dusky salamander)	NL	-	NL	NL	-	-	-	-	-	-	NR	G3
<i>D. brimleyorum</i> (Ouachita dusky salamander)	-	NL	-	-	-	-	-	-	-	-	SC	NR
<i>D. santeetlah</i> (Santeetlah dusky salamander)	-	-	-	-	-	-	-	NL	-	NL	NR	G3/Q
<i>D. welteri</i> (Black Mtn. dusky salamander)	-	-	-	-	NL	-	-	-	-	WM	NR	NR
<i>Phaeognathus hubrichti</i> (Red Hills salamander)	T	-	-	-	-	-	-	-	-	-	T	NR
<b>Plethodontinae</b>												
<i>Aneides aeneis</i> (green salamander)	NL	-	-	R	NL	-	E	E	NL	WM	SC	NR



Table 1. Continued.

Amphibian Taxa	State Lists										Federal Rank	TNC Rank
	AL	AR	FL	GA	KY	LA	MS	NC	SC	TN		
<i>P. kisatchie</i> (Louisiana slimy salamander)	-	NL	-	-	-	NL	-	-	-	-	NR	G3/Q
<i>P. ouachitae</i> (Rich Mountain salamander)	-	NL	-	-	-	-	-	-	-	-	NR	G2/G3
<i>P. petraeus</i> (Pigeon Mountain salamander)	-	-	-	R	-	-	-	-	-	-	NR	G1/G2
<i>P. teyahalee</i> (southern Appalachian salamander)	-	-	-	NL	-	-	-	NL	NL	NL	NR	G3/Q
<i>P. websteri</i> (Webster's salamander)	NL	-	-	NL	-	NL	NL	-	E	-	NR	NR
<i>P. wehrlei</i> (Wehrle's salamander)	-	-	-	-	NL	-	-	T	-	NL	NR	NR
<i>P. welleri</i> (Weller's salamander)	-	-	-	-	-	-	-	SC	-	NL	NR	NR
<i>P. yonahlossee</i> <sup>3</sup> (Yonahlossee salamander)	-	-	-	-	-	-	-	SC	-	NL	NR	NR
FROGS												
Hylidae												
<i>Hyla andersonii</i> (Pine Barrens treefrog)	NL	-	SC	-	-	-	-	-	T	-	NR	NR
<i>H. gratiosa</i> (barking treefrog)	NL	-	NL	NL	NL	NL	NL	NL	NL	WM	NR	NR
<i>Pseudacris brachyphona</i> (mountain chorus frog)	NL	-	NL	-	NL	-	NL	SC	-	NL	NR	NR
<i>P. streckeri illinoensis</i> (Illinois chorus frog)	-	NL	-	-	NL	-	-	-	-	-	SC	NR

Table 1. Continued.

Amphibian Taxa	State Lists										Federal Rank	TNC Rank
	AL	AR	FL	GA	KY	LA	MS	NC	SC	TN		
Ranidae												
<i>Rana capito aesopus</i> (Florida gopher frog)	-	-	SC	NL	-	-	-	-	-	-	SC	G3
<i>R. c. capito</i> (Carolina gopher frog)	-	-	-	NL	-	-	-	SC	NL	-	SC	NR
<i>R. c. sevensi</i> (dusky gopher frog)	NL	-	SC	-	-	NL	E	-	-	-	SC	G3
<i>R. lyckescheri</i> (river frog)	NL	-	NL	NL	-	-	NL	SC	NL	-	NR	NR
<i>R. okaloosae</i> (Florida bog frog)	-	-	SC	-	-	-	-	-	-	-	SC	G2

<sup>1</sup> Species names and distributions based on Conant and Collins, 1991.<sup>2</sup> Arkansas and Missouri populations only.<sup>3</sup> Listed in North Carolina as *Plethodon longicrus*, the crevice salamander.



east is 126 (Conant and Collins, 1991). Therefore, the imperiled species represent 37 percent of the total amphibian fauna of the Southeast, with 45 percent of salamander and 18 percent of frog species being imperiled.

## AMPHIBIAN RESOURCE MANAGEMENT IN THE SOUTHEAST

Over the past several years, herpetologists have begun sharing their observations on declining amphibian populations with the general public (Blaustein and Wake, 1990; Vitt et al., 1990; Livermore, 1992; Yoffe, 1992). The dramatic population declines seen in some areas of the world have not been demonstrated in the Southeast. Granted, range-wide historical data are few and generally not comprehensive enough to provide an adequate baseline with which to compare current distributions. However, given the destruction, degradation, and fragmentation of imperiled amphibian habitats in the Southeast, there can be little doubt that the distribution of many species has probably contracted from historical levels (Vial and Saylor, 1993; Pechmann and Wilbur, 1994).

The management of amphibians as a resource to be protected, in the traditional sense of wildlife management, has only recently been addressed (Szaro et al., 1988). Wildlife management has historically targeted game and other species which have a perceived economic value (Schemnitz, 1980). Amphibians generally do not fall into this category, and thus they have typically been ignored. Additional reasons for the limited management activities focusing on amphibians include a lack of information on the regional fauna; scarce resource dollars for management which are often specifically targeted for birds, mammals, or fish (e. g., Pittman/Robertson funds to states); a perception that amphibians are common and do not require management; and a general attitude that amphibians are not as important a component of ecosystems as other vertebrates. Further neglect may be a consequence of difficulties associated with studying fauna which are inactive for large portions of the day or year (Scott and Seigel, 1992). Lastly, most herpetologists do not have a background in resource management, and they seldom have directly participated in the development of resource management strategies.

Although the implementation of amphibian resource management is in its infancy, resource managers are beginning to show an interest in amphibians. This interest is being supported by researchers who are providing information to assist in planning management strategies (Seehorn, 1982; Dodd and Charest, 1988; Gibbons, 1988; Szaro et al., 1988; Dodd, 1991; Scott and Seigel, 1992; Dodd, 1993; Bookhout, 1994; Dodd and LaClaire, 1995; deMaynadier and Hunter, 1995; Dupuis et al., 1995). This link between managers and scientists is being strengthened in several ways. For example, a manual for wildlife managers that addresses management of both amphibians and reptiles is being developed by the U.S. Forest Service in cooperation with The Nature Conservancy (M. Robertson, U.S. Forest Service, pers. comm.). Scientific assessment methods to reliably determine amphibian rarity or commonness have also recently been standardized and made generally available (Jones, 1986; Corn and Bury, 1990; Heyer et al., 1994). In spite of this progress, the incorporation of amphibians into resource management plans remains rare, and funds for amphibian management projects are usually difficult to obtain from resource management agencies.

Although amphibians have generally been overlooked in the past, they have benefited when resource management strategies incidentally protected their habitats. In a few in-

**Table 2.** Summary of numbers of imperiled amphibians in the southeastern United States.

Amphibian Group	Federal Listed Species	Federal Species of Concern	State Listed Species	Species With TNC Global Rank <sup>1</sup>	Total Number <sup>2</sup>
Salamanders	1	12	26	20	39
Frogs	0	3	6	2	7

<sup>1</sup> This category reflects ranking systems of The Nature Conservancy and Natural Heritage Data Center Network.

<sup>2</sup> Total Number will be less than the sum of each row due to overlap in categories (see Table 1).

stances, amphibian populations and their habitats have been specifically targeted for protection, usually as a result of federal or state regulations.

## LEGISLATION AND REGULATION AS MANAGEMENT TOOLS

Legal protection afforded by federal and state regulations has been the basis for amphibian resource management. Federal legislation which may afford protection for amphibian resources includes the Clean Water Act, the Endangered Species Act, the Fish and Wildlife Coordination Act, the National Environmental Policy Act, the National Forest Management Act, and the National Wild and Scenic Rivers Act. As mentioned above, six southeastern states have non-game regulations which provide protection for state-listed species, and all ten southeastern states require scientific or commercial permits to collect at least some species of non-game wildlife. These permits can be denied on the basis of species rarity. There are also local zoning and land-use regulations which may offer some protection for amphibian resources.

The implementation of most environmental legislation has been reactive rather than pro-active (see Karr, 1990; Doppelt et al., 1993). For example, the intent of the Endangered Species Act is to provide a means to conserve the ecosystems upon which endangered and threatened species depend and to provide a program for the conservation of those species. Implementation of the Endangered Species Act often results in protecting individuals of a particular species on a case by case basis, but conservation of the habitats and ecosystems in which these species live has rarely been accomplished (Clark et al., 1994). Some legislation, such as the Clean Water Act, can target habitat directly. In general, enforcement of such environmental regulations is difficult and often directed towards only the most blatant violators.

Each of the six acts of federal legislation outlined below are intended, at least in part, to protect the quality of the environment and, as a result, have applicability to amphibian protection and management. The Clean Water, the Fish and Wildlife Coordination, and the National Wild and Scenic Rivers acts, specifically address protection of water resources. The Endangered Species, the National Environmental Protection, and the National Forest Management acts, address protection of species, protection of the human environment, and protection of our national forests and their resources, respectively.

The Clean Water Act (CWA) provides for the restoration and maintenance of the chemical, physical, and biological integrity of the Nation's lakes, rivers, streams, and coastal

waters. The CWA specifically regulates the discharge of any pollutant or the discharge of dredge or fill material into all waters of the United States including adjacent wetland ecosystems. Section 404 of the CWA defines a permit program to control dredging or filling activities. The U.S. Army Corps of Engineers (COE) has permit authority over waters of the United States (i.e., all waters affecting interstate and foreign commerce and translated by the U.S. Environmental Protection Agency [EPA] as any wetland habitat used by migratory birds). The EPA has an oversight role in promulgating guidelines for the permit program and has the authority to veto permits. The COE can issue General Permits for activities "similar in nature" and having minimal individual or cumulative adverse effects. One of these General Permits, Nationwide Permit 26, authorizes any dredge or fill activity in headwaters and isolated wetlands provided less than ten acres (approximately four ha) are impacted. In waters other than traditionally navigable waters, states may displace COE permitting (Blumm and Zaleha, 1989) and determine the size of wetlands to be regulated under dredge and fill permits. Many wetlands used for amphibian breeding are smaller than the size designated as jurisdictional by Nationwide Permit 26 or by state agencies.

The Fish and Wildlife Coordination Act (FWCA) was promulgated to allow development of water resources while conserving wildlife resources and environmental quality. The intent of the FWCA is to give wildlife conservation a coequal purpose or objective in federally funded or permitted water resource development proposals or projects. Federal agencies planning projects to develop water resources (e.g., the COE) must consult with the U.S. Fish and Wildlife Service and state game and fish agencies prior to seeking authorization for the action. The planning agency must give full consideration to measures recommended by these agencies to mitigate impacts to wildlife resources. This provides opportunity for amphibian management issues to become part of the decision-making review process. The agency carrying out the development project makes the final decision on wildlife mitigative measures, however.

The National Wild and Scenic Rivers Act (WSRA) created a system for designation and preservation of free-flowing rivers on private, state, or federal lands. A separate federal law is required for each Wild and Scenic River segment protected. Management areas for these congressionally designated rivers generally include adjacent corridors; however, the average acreage per river mile may not exceed 320 acres (about 130 ha) within the designated segment (Doppelt et al., 1993). Federal land management agencies must preserve designated river segments within their jurisdiction in free-flowing condition, protect water quality, and fulfill other national conservation purposes (e.g., protection of wildlife). The federal managing agency decides how best to protect the value of a river, but must consult with the EPA and state water pollution control authorities. Three rivers in the southern Appalachian Mountains have been designated Wild and Scenic Rivers under this Act. Implementation of the WSRA may benefit amphibians living in these watersheds. The three rivers are the Chattooga River in Georgia, North Carolina, and South Carolina, the Obed River in Tennessee, and the headwaters of the New River in North Carolina (Wallace et al., 1992).

The Endangered Species Act (ESA) specifically addresses the conservation of endangered species and the ecosystems on which they depend. Implementation of this Act is initiated by determining if a species meets the criteria to be designated an endangered or threatened species. This determination is made by reviewing a species' status based on the following five factors: the present or threatened destruction, modification, or curtailment

of its habitat or range; the overutilization for commercial, recreational, scientific, or educational purposes; disease or predation factors; the inadequacy of existing regulatory mechanisms; and other natural or man-made factors affecting the species' continued existence. Once a species is placed on the Endangered Species List, the ESA provides a number of methods to protect it and its habitat. Recovery Plans are developed and implemented for listed species. Legal protection provided by the ESA is described under Section 7 (actions of or supported by government agencies shall not jeopardize endangered species), Section 9 ("take" of endangered species is prohibited), and Section 10 (an incidental take permit may be obtained if an approved Habitat Conservation Plan has been developed). Section 6 of the Act describes provisions for states to receive federal funds to perform research on candidate and listed species. Management issues can be addressed through use of these funds, but in most cases research is in response to a need for status surveys or recovery tasks outlined in Recovery Plans. All states in the Southeast have Section 6 agreements with the U. S. Fish and Wildlife Service which require the states to provide protection for federally listed species.

The National Environmental Policy Act (NEPA) provides guidelines for federal agencies to follow in the course of performing their various activities. The laws, regulations, and policies of the United States must be administered in accordance with the policies of NEPA. Specifically, federal agencies are required to consult with each other when planning actions that may significantly affect the quality of the human environment. Consultation must occur prior to approval of projects, and a statement of environmental impacts that are likely to result from the actions must be formulated. The federal agency with the lead on the action must prepare an Environmental Impact Statement with input from the public, state and local governments, and all federal agencies with legal jurisdiction or special expertise. The Act offers the opportunity for input from agencies with the lead for natural resource protection, such as the U.S. Fish and Wildlife Service, in the development of mitigative measures which can offset impacts of the proposed action. These measures may provide a direct benefit to imperiled amphibians.

The National Forest Management Act (NFMA) governs stewardship of national forests which is the responsibility of the U.S. Forest Service. The major focus of NFMA is on interdisciplinary land management planning, including procedures for public participation in the decision making process. Forest management plans must provide for multiple uses of national forest lands and must incorporate the values of watersheds and fish and wildlife into planning documents. Guidelines are provided for the following: obtaining inventory data on the various renewable resources in order to maintain the diversity of plant and animal communities; allowing timber harvest only where water bodies are protected from detrimental changes in water temperature, blockage of flow, and deposits of sediment; and, ensuring that harvesting methods are carried out in a manner consistent with the protection of soil, watersheds, and fish and wildlife. As a result of NFMA, amphibian status surveys and research projects are being funded to provide data for improving resource management plans for national forests.

## **SPECIFIC MANAGEMENT PROGRAMS BENEFITING IMPERILED AMPHIBIANS**

The development of resource management programs for imperiled amphibians has been

hindered by the limited data available on species' distributions and population sizes. In order to improve this situation, distribution and status surveys of some southeastern amphibians have been initiated by state non-game and heritage programs, The Nature Conservancy, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the U.S. Department of Defense, and individual herpetologists. Funding for surveys has been provided by private landowners, state non-game programs, and by federal agencies. The Alabama Natural Heritage Program and the U.S. Fish and Wildlife Service have initiated the Alabama Herpetological Atlas Project to provide baseline data on reptiles and amphibians in Alabama. These efforts represent the beginnings of a region-wide database on amphibian distribution and abundance.

Specific management projects for imperiled amphibians are discussed below. Since resource management funds are not generally allocated solely for imperiled amphibians, total dollars spent directly for amphibian management could be provided for only a few of the projects discussed. Most of these management programs are ongoing and are being modified as results dictate. Of course, their success or failure cannot be judged until adequate long-term monitoring studies (at least a generation time for each species) have been completed.

### **Amphibian Management on Federal Lands**

Resource management addressing amphibians has generally been tied to timber management on federal lands by the U.S. Forest Service and the Department of Defense. Timber management on these lands has most commonly focused on communities or ecosystems. In some cases, specific actions which benefit amphibians have been included. These include strategies to maintain moist environments and to protect wetland and stream habitats. Streamside management zones and timber harvests, limited to single tree selection, have been used to maintain forest canopy and soil moisture at a level more suitable to imperiled amphibians than would clearcut harvests. Many pond breeding amphibians require temporary wetlands for reproduction. Management actions used to protect these ponds have included the prescribed burning of temporary wetlands, the termination of fish stocking, the curtailment of the use of breeding ponds as fire breaks, and the creation of temporary ponds.

Studies have been undertaken on a number of national forests in different states to examine the effects of different harvest methods and successional impacts on amphibian and reptile populations. Additional studies have focused on surveys for imperiled amphibians on lands managed by the U.S. Forest Service and the Department of Defense. These studies have provided information that will be used in developing timber management plans.

Many federally owned lands in the Southeast have suitable habitat for three imperiled amphibians endemic to areas historically dominated by longleaf pine forests: the gopher frog (*Rana capito*), the striped newt (*Notophthalmus perstriatus*), and the flatwoods salamander (*Ambystoma cingulatum*). Managers of these federal lands have, or plan to, tailor their resource management plans to include measures to protect these amphibians.

A project has been undertaken in the Conecuh National Forest of Alabama to restore Nellie Pond, a breeding site of the dusky gopher frog (*Rana capito sevosa*). Due to the relatively recent introduction of predaceous fish to the pond by fishermen, tadpoles of the gopher frog, which historically bred in this ephemeral pond, were no longer surviving to metamorphosis. In 1992, U.S. Forest Service personnel drained the pond, removed as many fish as possible, and used rotenone to kill the remaining fish. The pond refilled

naturally. Signs were erected to inform the public of the importance of maintaining the pond without a fish community. Public hearings were held to receive public input. Dusky gopher frog eggs were collected from a nearby pond and were raised in a laboratory until they were large tadpoles. They were then introduced into Nellie Pond, and during subsequent monitoring, metamorphic frogs were observed exiting the pond. Continued monitoring will be needed to determine the long-term success of this project. The project cost, approximately \$11,000, was supported in part by a timber sale resulting from slash pine thinning of the surrounding habitat (R. Lint, U.S. Forest Service, pers. comm.). In addition to funding the project, the timber thinning improved the habitat for the resident upland-dwelling adult dusky gopher frogs.

The only breeding pond for the dusky gopher frog in Mississippi occurs in the DeSoto National Forest. Projects have been funded by the U.S. Forest Service and the U.S. Fish and Wildlife Service to study gopher frog life history and to improve the pond habitat for this species. Forest management plans since 1994 have incorporated the needs of the frog and will continue to be adapted as new data become available.

In Florida, status surveys have been conducted for the Florida gopher frog (*Rana capito aesopus*) and the striped newt in the Ocala National Forest (ONF) (Telford, 1993). In addition to these surveys, a study of the effects on amphibians of different timber cutting regimes around selected temporary ponds in the ONF has been initiated (K. Greenberg, U.S. Forest Service, pers. comm.). Results of these studies will be incorporated into resource management plans for the forest. Additional surveys have been funded by the U.S. Forest Service and the U.S. Fish and Wildlife Service to determine the distribution of the flatwoods salamander, formerly considered a Category 2 federal candidate species, in Florida's Apalachicola National Forest (Palis, 1992, 1993, 1995a) and Osceola National Forest (Palis, 1992; D. Printiss, Florida Natural Areas Inventory, pers. comm.). These distribution data will be used to help formulate resource management plans for the salamander on both of these national forests.

The U.S. Department of Defense (DOD) has funded surveys for rare vertebrates, including the three aforementioned longleaf pine endemic amphibians, on a number of military bases in the Southeast. Surveys on Camp Blanding in Florida have been conducted by biologists with the Florida Natural Heritage Program. Management steps to enhance populations of the Florida gopher frog and striped newt were included in their summary report (Hipes and Jackson, 1994). A faunal survey for rare vertebrates on Fort Benning in Georgia was initiated in 1994 and will continue through 1997 (P. Laumeyer, U.S. Fish and Wildlife Service, pers. comm.). Prior to this study, a breeding site for the imperiled dusky gopher frog had been found on the base. For this reason, biologists conducting the surveys are especially interested in searching for additional localities for the gopher frog and other rare amphibians. Data collected during the survey will be used in future Fort Benning resource management plans. Biologists with The Nature Conservancy, funded by DOD, have surveyed Fort Stewart in Georgia for rare plants and animals including the Carolina gopher frog (*Rana capito capito*), the striped newt, and the flatwoods salamander (K. Lutz, The Nature Conservancy, pers. comm.). The distribution information generated by this study is being used to help develop a resource management plan (L. Swindell, DOD, pers. comm.). Additional studies on flatwoods salamander and striped newt life histories will continue through the year 2000 to determine how best to



manage for these species on Fort Stewart (L. Swindell, DOD, pers. comm.).

A five-year Natural Resources Management Plan has been developed by the DOD for Eglin Air Force Base in Florida (Department of Defense, 1993). The goals of the plan are to protect plant communities and to restore ecosystem function and viability through careful land management. Eglin Air Force Base encompasses what may be the largest remaining, relatively intact longleaf pine/turkey oak forest in the United States. The presence of the federally listed red-cockaded woodpecker has focused planning on the restoration and maintenance of the sandhill community. The longleaf pine sandhills and flatwoods at Eglin Air Force Base are also habitat for the dusky gopher frog and the flatwoods salamander. Population surveys and identification of temporary pond breeding sites used by these two imperiled amphibians have been completed (Palis, 1995b). Habitat restoration, as described in the management plan, will benefit both species.

The U.S. Department of Energy (DOE) has funded long-term studies on reptiles and amphibians at the DOE Savannah River Site (SRS) in South Carolina. A considerable database has been developed for the site by researchers at the Savannah River Ecology Laboratory (SREL) (see Gibbons and Semlitsch, 1991). The U.S. Forest Service manages the forest on the SRS for timber production. Portions of the SRS have been set aside for protection, but at present there are no specific management goals for imperiled amphibians (B. Jarvis, U.S. Forest Service, pers. comm.). A project started at the site in the late 1980s provided potential benefits to imperiled amphibians through the creation of several temporary ponds as replacements for a pond that was destroyed. This attempt to replace the destroyed wetland with newly created ones of equal value was only partially successful (J. Pechmann, SREL, pers. comm.). The new ponds were dug near the periphery of the construction site and the location of the original wetland. Re-creating the original hydrologic conditions was problematic. Initially, the created ponds drained more frequently and remained dry for longer periods of time than the original temporary pond. Later, when liners were used to create an impervious bottom layer, the ponds became too permanent. As a result, species composition differed in the created ponds from the original wetland. Uncommon species, formerly present in the destroyed pond, were not recorded in the created ponds.

Projects on national forest lands in the southern Appalachian Mountains, which are habitat for a number of imperiled amphibians (see Table 3), are being carried out in the Daniel Boone National Forest in Kentucky, and the Nantahala and Pisgah national forests in North Carolina. In the Daniel Boone National Forest, traditional wildlife ponds have been created for many years for use by the resident deer population. U.S. Forest Service biologists, interested in managing for amphibians, modified the design of these ponds by varying their depth and shape, and by adding logs and branches to encourage colonization by amphibians. Eight of these newly created ponds were monitored during the first year (1994) after construction. Six species of frogs and two species of salamanders were found in the ponds, including an imperiled species, the mountain chorus frog (*Pseudacris brachyphona*) (J. MacGregor, U.S. Forest Service, pers. comm.).

On the Nantahala and Pisgah national forests, a study of the distribution and habitat of the Junaluska salamander (*Eurycea junaluska*) was completed in 1995. The results of this study will be used in the development of a conservation strategy for this imperiled species. Discussion of a multi-agency conservation agreement was initiated in May 1996 between the U.S. Forest Service, the U.S. Fish and Wildlife Service, the North Carolina Depart-

**Table 3.** Imperiled amphibian fauna of the southern Appalachian Mountains. All = endemic, Part = part of range within southern Appalachian Mountains.

Taxon	All	Part
<b>SALAMANDERS</b>		
Plethodontidae		
Desmognathinae		
<i>Desmognathus aeneus</i> , seepage salamander		X
<i>D. santeetlah</i> , Santeetlah dusky salamander	X	
<i>D. welteri</i> , Black Mountain dusky salamander		X
Plethodontinae		
<i>Aneides aeneus</i> , green salamander		X
<i>Eurycea aquatica</i> , dark-sided salamander	X	
<i>E. junaluska</i> , Junaluska salamander	X	
<i>E. longicauda longicauda</i> , longtail salamander		X
<i>E. lucifuga</i> , cave salamander	X	
<i>Gyrinophilus palleucus</i> , Tennessee cave salamander		X
<i>G. porphyriticus</i> , spring salamander		X
<i>Hemidactylium scutatum</i> , four-toed salamander		X
<i>Plethodon aureolus</i> , Tellico salamander		X
<i>P. dorsalis</i> , zigzag salamander		X
<i>P. petraeus</i> , Pidgeon Mountain salamander	X	
<i>P. teyahalee</i> , southern Appalachian salamander	X	
<i>P. websteri</i> , Webster's salamander		X
<i>P. wehrlei</i> , Wehrle's salamander		X
<i>P. welleri</i> , Weller's salamander	X	
<i>P. yonahlossee</i> , Yonahlossee salamander <sup>1</sup>	X	
<b>FROGS</b>		
Hylidae		
<i>Pseudacris brachyphona</i> , mountain chorus frog		X

<sup>1</sup> Listed in North Carolina as *Plethodon longicrus*, the crevice salamander.

ment of Transportation, and a regional power company (R. McClanahan, U.S. Forest Service, pers. comm.). Additionally, a database on the distribution of another imperiled species, the green salamander (*Aneides aeneus*), has been compiled for these two national forests. Using this database, timber operations are modified when needed, on a case by case basis, to ensure that green salamanders and their habitat are protected (R. McClanahan, U.S. Forest Service, pers. comm.).

The Ouachita Mountains of Arkansas and Oklahoma are also habitat for a number of imperiled amphibians. Two imperiled species, the Fourche Mountain salamander (*Plethodon fourchensis*) and the Caddo Mountain salamander (*P. caddoensis*), are endemic to Arkansas and virtually all of their habitat occurs within the Ouachita National Forest. Both species occur on steep wooded slopes and are vulnerable to reductions in soil moisture. The U.S. Fish and Wildlife Service, the U.S. Forest Service, and the Arkansas Game and Fish Commission have developed a memorandum of understanding for each species to benefit their conservation. Since 1993, these three agencies have been working together to determine

the distribution of these salamanders and to monitor their populations. In addition, timber harvest and selective forest thinning have been restricted in streamside management zones and on slopes greater than 35 degrees to protect salamander habitat. The management of these salamanders has been incorporated into the larger, ecosystem-level Ouachita National Forest Management Plan.

Additional research in the Ouachita National Forest, part of the Ouachita Mountains Management Research Project, examines the distribution of amphibians and reptiles in the forest. Cooperators on this project, which was initiated in 1992 and continues through 1997, include the U.S. Forest Service, Weyerhaeuser Company, Oklahoma State University, the University of Arkansas, and the National Council of the Paper Industry for Air and Stream Improvement, Inc. (NCASI) (B. Wigley, NCASI, pers. comm.). Data on amphibian and reptile species abundance and community composition are being collected at both the forest-stand level and landscape-level in four watersheds with different histories of silviculture and intensity of timber management. A study of forest stands compares surveys on sites managed under three different regimes: single-tree selection (not clearcut), even-age management (clearcut, burn, replant), and eighty-year mature forest. Results of the surveys will be used to examine the effects of forest succession on the distribution of amphibians and reptiles (D. Crosswhite, Oklahoma State University, pers. comm.). A landscape-level study used satellite imagery to classify habitats from which different size study plots were chosen. The study plots are being censused to determine amphibian and reptile community composition. These data will be used to compare amphibian population diversity in different size patches and to determine if certain patches have higher value than others for amphibians. Geographic Information System (GIS) methods are being tested as a technique to make predictions about species composition on forest patches. The results of these studies will be used in preparing a management plan for the Ouachita National Forest in 1997 or 1998. This plan will encompass management for imperiled amphibians as well as other rare vertebrates (R. Perry, U.S. Forest Service, pers. comm.).

The U.S. Department of the Army, Corps of Engineers is planning a study at Haines Island Park in Alabama on the federally threatened Red Hills salamander (*Phaeognathus hubrichti*) (B. Peck, COE, pers. comm.). The study will focus on the development of a management plan to promote the recovery of the Red Hills salamander. An additional study at the site, initiated in 1995 and funded by the U.S. Fish and Wildlife Service, is testing the feasibility of using implanted passive integrated transponder (PIT) tags to monitor salamanders. This technique shows promise for use in mark and recapture studies and as a method to study burrow use by the animals. Data from this study will be valuable in determining management strategies for the Red Hills salamander.

### **Amphibian Management on Private and State Lands**

While most amphibian management has been the result of forest management on public lands, some management has been directed at imperiled amphibians on private lands. Principles of conservation biology have rarely been used as guidance for private land-use planners. However, some private landowners are beginning to incorporate ecological principles into economic land-use decisions. O'Connell and Noss (1992) outlined ecological criteria for use in developing appropriate management plans and general methods for monitoring the effectiveness of those programs. Private land management plans that have

accommodated both land-use objectives and the needs of rare species often use mitigation, restoration, and compensation to meet these goals. Projects directed at protection or enhancement of imperiled amphibian populations on private lands have been undertaken by the International Paper Timberlands Operating Company, Ltd. in Alabama; The Nature Conservancy in North Carolina; the National Council of the Paper Industry for Air and Stream Improvement, Inc. in Alabama, Florida, and Georgia; and a development company in Florida.

The International Paper Timberlands Operating Company, Ltd. (IPTOC) has developed a Habitat Conservation Plan (HCP) for the federally threatened Red Hills salamander in Conecuh and Monroe counties in Alabama (International Paper Timberlands Operating Company, Ltd., 1993). The plan was developed in cooperation with the U.S. Fish and Wildlife Service as part of an application for an incidental take permit under Section 10 of the ESA. The ESA defines the term "take" as meaning to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or to attempt to engage in any such conduct. Section 10 of the ESA allows issuance of permits if a taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. The underlying philosophy of an HCP is that resource management on private lands (e.g., silviculture) and endangered species management objectives can be integrated for the benefit of both. The cost for developing the IPTOC plan was between 50,000 and 75,000 dollars, and included costs for species surveys, plan preparation, and training of field personnel (J. McGlinchy, IPTOC, pers. comm.).

The primary form of incidental take under the aforementioned Section 10 permit is habitat modification resulting from timber harvesting activities. To address this issue, results of habitat and population surveys were used to classify Red Hills salamander habitat as optimal, sub-optimal, or marginal. The HCP includes provisions to minimize take by only allowing forest management activities in marginal salamander habitat and to avoid and mitigate the impacts of take by establishing high-value habitat areas totaling 4,500 acres (about 1,821 ha) where no timber harvesting will occur. These habitats represent 92 percent of all occupied Red Hills salamander habitat on IPTOC lands. In forested buffer zones, adjacent to the areas where no harvest will occur, timber harvesting may occur, but a 50 percent canopy cover will be maintained. The plan includes methods for ongoing habitat and species monitoring and procedures for implementing contingency plans and amending the HCP. The permit allows incidental take for a 30-year period, with a comprehensive review conducted every ten years.

The North Carolina field office of The Nature Conservancy, in cooperation with the North Carolina Herpetological Society and the North Carolina State Museum of Natural Sciences (NCSMNS), has worked to improve breeding habitat for the Carolina gopher frog on properties they manage in the state. The imperiled Carolina gopher frog is listed as a species of special concern in North Carolina. The project involved altering the hydrology of one pond and it required creating two ponds on TNC properties, and creating one pond on North Carolina Department of Agriculture property (A. Braswell, NCSMNS, pers. comm.). The five-year project was directed by the NCSMNS and funded by the U.S. Fish and Wildlife Service at a cost of approximately 10,000 dollars.

The existing pond was converted from a permanent pond to a temporary pond by removing the resident fish and adjusting the contour to allow the pond to dry completely. The three created ponds were dug in areas of suitable habitat. They were inoculated with aquatic vegetation, a nutrient source, and gopher frog tadpoles from local populations.

Metamorphic frogs were observed leaving two of the created ponds, but thus far, no adults have returned to the ponds to breed (A. Braswell, NCSMNS, pers. comm.).

Difficulties were encountered in this project when trying to establish ponds of a temporary nature. The converted fish pond remains too permanent and may require more modifications to make it shallower and to allow it to dry completely on a seasonal basis. One of the created ponds may be too ephemeral. Although no gopher frog breeding has been observed in any of the four ponds, the eastern tiger salamander (*Ambystoma tigrinum tigrinum*), listed as threatened in North Carolina, has bred in the converted pond. Many other amphibian species have also used the ponds for breeding.

The National Council of the Paper Industry for Air and Stream Improvement, Inc., a non-profit research organization associated with the forest products industry, is conducting several amphibian research projects which may provide benefits to southeastern imperiled amphibians. One of these projects involves studies on the effects of various timber practices on amphibians and wetlands at a site in Alachua County in Florida. Imperiled amphibians are not specifically targeted in this project; however, researchers hope the results of the study will provide a means to integrate the needs of sustainable industrial forestry with those of maintaining biodiversity (B. Wigley, NCASI, pers. comm.).

A second research project, funded by participating American Forest and Paper Association member timber companies and conducted by NCASI, targets three imperiled longleaf pine endemics, the gopher frog, the striped newt, and the flatwoods salamander, on lands owned or managed by the timber companies. Potential breeding sites for these three species are being surveyed within selected counties of Alabama, Georgia, and Florida. The three-year project was initiated in 1995. Once the surveys are completed, it is hoped that the distribution data from the study will be used by the timber companies to develop resource management plans that protect these three species.

In Lake and Sumter counties in Florida, the development plan for a 3,200 acre (about 1,295 ha) residential area, The Villages of Lake Sumter, included on-site protection for the Florida gopher frog. The protection was achieved through mitigation and compensation resulting from the Development of Regional Impact (DRI) review process required by the state of Florida for large scale development projects (R. McCann, Florida Game and Fresh Water Fish Commission, pers. comm.). Within the development, a 126.2 acre (about 51 ha) preserve was created to protect a number of vertebrate species including the gopher tortoise, the burrowing owl, and the southeastern kestrel. Part of the preserve (33.2 acres or about 13.4 ha), including a 0.25 acre (about 0.1 ha) sinkhole pond breeding site, has been set aside to protect the Florida gopher frog. Habitat restoration on the preserve, which was formerly part of a cattle ranch, occurred as development of the site progressed. This included exotic vegetation removal, mowing, and burning. A wildlife habitat management plan written for the preserve, as part of a conservation easement, contains restrictions on land-use in the preserve and habitat management requirements, including ones specifically addressing the gopher frog. The Florida Game and Fresh Water Fish Commission (FGFWFC) holds the conservation easement on the property which gives the FGFWFC interest in the title. The development company must adhere to the management plan as outlined in the easement. Management activities are intended to be financially supported in perpetuity through a homeowners' association fee. Parts of the management plan addressing the gopher frog include monitoring the water quality and hydrology of the gopher

frog breeding pond, protecting the pond from residential and golf course drainage, monitoring frog activity at the breeding pond, managing the upland areas used by the gopher frog with prescribed burning, and providing information to the public on the frog and the importance of protecting its habitat (R. Ashton, Applied Technology and Management, Inc., pers. comm.).

## **FUTURE OF AMPHIBIAN MANAGEMENT IN THE SOUTHEAST**

In the future, successful management of amphibian resources in the Southeast will require a coordinated effort between land managers on both public and private lands. Fortunately, there is a growing awareness within federal and state agencies and private organizations about the importance of protecting our native amphibian fauna. The development of quality management plans will require the expertise of herpetologists, the skill of resource managers, the support of public citizens, and the creativity and cooperation of all parties involved.

Ideally, the development of most amphibian management plans should begin with an inventory and threat assessment of the amphibian community of concern. High priority species and habitats, as well as research needs should be identified during this inventory and threat assessment. Site-specific, single-species or ecosystem conservation strategies must be based on the threats to these species and habitats and should consider changes in species distributions and population status. Resource management plans should include criteria to determine effectiveness and measures of progress, as well as provisions to allow for modifications as new management information becomes available. Once a plan has been formulated, funding should be provided at a level sufficient to fully implement the management plan and to complete long-term monitoring studies.

Determining the distribution of imperiled amphibians and the threats they face can be difficult and time consuming. State non-game and heritage programs, The Nature Conservancy, the U.S. Fish and Wildlife Service, and interested herpetologists have begun surveys to determine the distribution and status of many imperiled amphibians in the Southeast. Additional data on amphibian status and distribution can be found by searching museum records and by gathering anecdotal information from experienced herpetologists. The Declining Amphibian Populations Task Force of the International Union for the Conservation of Nature/Species Survival Commission (IUCN/SSC) has developed a database called FROGLOG to summarize available information. Data from all of these sources have been used to prioritize species and communities that are imperiled (Natural Heritage Data Center Network, 1993). More rigorous methodologies, such as that developed by Millsap et al. (1990) in Florida, are needed for assessing priorities for research and monitoring based on species imperilment.

The difficulty in assessing priorities becomes apparent when looking at the literature published on the status of amphibian populations in the Southeast. There is a growing body of work documenting population declines on sites where habitats have been degraded or destroyed (Vickers et al., 1985; Enge and Marion, 1986; Ash, 1988; Dodd, 1991; Raymond and Hardy, 1991; Petranks et al., 1993; Phelps and Lancia, 1995; Means et al., 1996). The long-term effects of these declines to the species involved are unclear (Ash and Bruce, 1994). Clearly, when the habitat of a given population is destroyed, that population has gone or will shortly go extinct. Many species may be unable to recolonize areas after local extinctions, especially when unsuitable habitat exists between the extinct



population and extant populations. In cases where the habitat is degraded but population stability is documented, the stability may simply reflect the persistence of long-lived individuals (Blaustein et al., 1994). On the other hand, several long-term studies have demonstrated that wide fluctuations in population numbers may be characteristic of amphibians (Pechmann et al., 1991; Hairston and Wiley, 1993). Also, many amphibians can survive prolonged drought or lack of food, and they may persist for long periods if the essential aspects of their habitat can be protected (Scott and Seigel, 1992). Long-term population studies, for at least one complete generation turnover of the monitored population, will be needed to determine the significance of declines and to critically assess the imperilment of many southeastern amphibians (Franklin, 1989; Blaustein et al., 1994). In the case of some amphibians, these studies may need to be extended to 15 or more years.

Other research needs will become evident after inventories and threat assessments are completed. Herpetologists from the public and private sectors need to become actively involved in studies that involve resource management of imperiled amphibians. Data are needed for use in the development of population and habitat viability models. For example, habitat requirements (both adult and larval), spatial use, and population structure are relatively unknown for many species. Research is also needed on the taxonomy and ecology of imperiled amphibians. Groups such as the plethodontids, *Necturus* spp., *Pseudobranchius* spp., and the ranid complexes may contain more species than presently described. Virtually nothing is known of the genetic diversity of rare amphibian populations (Stiven and Bruce, 1988). Without basic information about a species' biology, conservation programs will be based on assumptions that may not ensure the protection of amphibian populations (see Scott and Seigel, 1992; Underwood, 1995). The best available scientific information is needed to develop sound conservation strategies. This information should be continually updated to identify and investigate new management techniques and to critically assess the value of current conservation activities.

Species with specialized habitats or very limited distributions, such as the Red Hills salamander or the Fourche and Caddo mountain salamanders discussed above, can be protected by developing site specific management plans with a narrow focus. Other wide-ranging species may occur in multiple states and will require a management plan directed at ecosystem or watershed protection. The following discussion outlines management plan development for three areas which could improve conservation of a large portion (30 of 46 species) of the imperiled amphibians in the Southeast, namely, the southern Appalachian Mountains, the Mobile River Basin, and the longleaf pine forest ecosystem. A watershed management approach can be used to develop a conservation plan for both the southern Appalachian Mountains and the Mobile River Basin. A plan developed for the forests of the longleaf pine ecosystem will involve land-use management across watersheds, as well as wetlands management within geographically separated forests.

### **Southern Appalachian Mountains**

The southern Appalachian region encompasses portions of Alabama, Georgia, Kentucky, North and South Carolina, and Tennessee. The imperiled amphibian fauna in this region, within the Blue Ridge and Ridge and Valley physiographic provinces, includes one frog and 19 salamanders (see Table 3). The frog is the mountain chorus frog and the salamanders are species within six genera of the family Plethodontidae. Eight of the sala-

manders are endemic to the southern Appalachian Mountains. These 20 amphibians inhabit areas adjacent to or in association with high-gradient streams. The streams are the headwaters of many major river systems, and the water originating from these watersheds is an important resource for major metropolitan areas (Wallace et al., 1992). Since rivers are open, directional systems, protection of any segment requires protection of the entire upstream network along with the surrounding landscape (Sedell et al., 1990). Within the southern Appalachian Mountains, watershed impacts occur as a result of forestry and surface mining activities, and industrial, agricultural, and municipal waste-water inputs.

A management plan for imperiled amphibians in watersheds throughout the Southern Appalachian Mountains should begin with a forest management plan. Aquatic amphibians and terrestrial species with aquatic larval stages are sensitive to degraded stream and wetland quality. Completely terrestrial southern Appalachian salamanders are sensitive to modifications in prevailing temperature, humidity, or soil moisture because adults lack lungs and gas exchange must occur through moist skin (Duellman and Trueb, 1986). Clearcutting and large-scale canopy removal can have negative effects on the quality of both aquatic and terrestrial habitats. Vegetation removal increases stream flow and water temperatures and reduces the input of coarse woody debris and other organic matter after cutting. Reductions in the quality of aquatic habitats can also occur through sedimentation. Loss of soil stability and sedimentation results from logging and associated practices such as road building (Anderson et al., 1976). In addition, where the forest has been removed, streams are decoupled from self-regulatory mechanisms within the watershed and they become more hydrologically unstable (Sedell et al., 1990). The quality of terrestrial habitats is reduced when canopy removal eliminates shading and increases temperatures and moisture loss at the soil surface.

Habitat destruction and degradation resulting from timbering operations may create problems for long-term survival of imperiled amphibians (Kramer et al., 1993; Petranka et al., 1993). Several studies in the southern Appalachian Mountains have demonstrated declines in salamander numbers after clearcutting (Ash, 1988; Petranka et al., 1993; Ash, 1994). Petranka et al. (1993) found that numbers of salamanders on study plots in the Pisgah National Forest in North Carolina were five times higher in mature forest stands than in clearcuts. Species richness also was higher in the mature stands. Clearcuts contained, on average, about 50 percent of the species found in mature forest sites. Ash (1988, 1994) studied a site in Nantahala National Forest near Highlands, North Carolina, for over 15 years. Salamanders were surveyed on two clearcut and two control plots. Numbers of Jordan's salamanders (*Plethodon jordani*) collected on clearcut plots ranged from 40 percent of the number on forested plots during the first summer after cutting to zero the fourth summer. By the sixth year after cutting, salamanders had returned to clearcut plots and by the fifteenth year, salamander numbers exceeded 50 percent of those found on forested plots.

Additional threats to imperiled amphibians can occur through impacts to the watershed resulting from surface mining and associated acid mine drainage, industrial and municipal wastes, and acid precipitation (Wallace et al., 1992). Numerous conflicts exist between commercial and other economic interests, private citizens, and the federal government over land and stream use in the southern Appalachian Mountains. Watershed protection in this sensitive area will require compromise and cooperation between these groups. There are strong, vested economic considerations in continuing practices that contribute to environmental degrada-

tion. In many cases, adequate knowledge exists to sharply curtail much of the stream degradation; however, it has been difficult to transfer technology from researchers to those engaged in forestry, agriculture, and development (Wallace et al., 1992). Public education is needed to provide alternatives to harmful practices and to demonstrate the long-term benefits of quality water resources. Public involvement at the local level is imperative. Cooperation is needed between the private sector and government agencies to share responsibility for both water quality degradation and improvement. Adequate laws must be enacted to protect water quality. In addition to regulation, government could support water quality improvement practices undertaken by the private sector through tax breaks or other economic incentives.

To protect imperiled amphibians in the Blue Ridge and Ridge and Valley physiographic provinces of the southern Appalachian Mountains, a region-wide conservation plan is needed. Core areas within the region, and connecting linkages or corridors of habitat for exchange of individuals and their genes, should be defined for each species (Mitchell, 1994; Dupuis et al., 1995). Streamside management zones may act as refugia and centers of dispersal on sites where timber has been harvested (Foley, 1994). Recommendations to preserve cool, moist habitats within harvested areas include maintaining logs and snags as moist microhabitats and retaining some understory as a source of shade (Dupuis et al., 1995). The core areas should be protected from further degradation by the maintenance of natural riparian and hardwood forest areas and reduction of fragmentation, isolation, and edge effects (Mitchell, 1994). A plan of this scope will also require public education on the importance of conservation efforts to protect the habitat and its imperiled species.

The U.S. Fish and Wildlife Service (1995) has completed an ecosystem management plan of this scope for the Southern Appalachian Ecosystem (SAE). Many of the components described above have been incorporated into the plan. The purpose of the plan is to outline goals, objectives, and strategies to protect and restore U.S. Fish and Wildlife Service (USFWS) trust resources and ecological integrity within the SAE. A number of initiatives are described in the plan which, if implemented, would benefit imperiled amphibians. These include strategies for projects on aquatic systems, riparian restoration, declining amphibian populations, education and outreach, and wetland restoration. The USFWS is just one of many partners whom share responsibility for ecosystem health. Additional partners include other federal agencies (e.g., U.S. Forest Service, U.S. National Park Service), state and local agencies, communities, organizations, and corporate and other private landowners. The four major goals and objectives in the SAE plan are as follows:

- 1) Protect, restore, and enhance habitats and essential processes necessary to maintain healthy biological diversity in SAE. The objective is to reverse the decline of communities and species groups most "at risk" through an inventory and assessment of threats, then initiate the development and implementation of protection, management, and monitoring strategies for high priority species and habitats.
- 2) Promote and support compatible and sustainable uses of ecosystem resources. The objective is to reduce the overuse and/or exploitation of biological and cultural resources and emphasize cooperation through partnerships to develop strategies to increase compliance with federal and state regulations.
- 3) Increase public knowledge and support for ecosystem resources and their management. The objective is to promote stewardship of ecosystem resources, emphasizing cooperation built via partnerships.

- 4) Increase the coordination and cooperation among agencies and organizations. The objective is to enhance the effective and efficient management of our shared natural resources.

### Mobile River Basin

The Mobile Basin includes the Mobile, Tombigbee-Black Warrior, and Alabama-Coosa-Tallapoosa river systems. Total drainage area prior to the construction of the Tennessee Tombigbee Waterway included more than half of the state of Alabama and portions of Georgia, Mississippi, and Tennessee (Livingston, 1992). Two imperiled amphibians occur in this drainage, the Black Warrior waterdog (*Necturus* sp.), and the one-toed amphiuma (*Amphiuma pholeter*). Water quality and the habitat of these two aquatic species have been degraded in the Mobile River Basin due to impoundment; channelization; dredging; coal, sand, and gravel mining; industrial and municipal discharge; and nonpoint discharge and run-off. All streams surveyed by Bailey (1992, 1995) for the waterdog, which occurs in the Black Warrior River system, showed some degree of degradation from sedimentation, and many appeared to be biologically depauperate. Bailey (1995) felt that surface mining was probably the greatest threat to the integrity of waterdog habitat, and that prospects for the long-term survival of the species were poor unless conditions in the watershed improved.

The Mobile River Basin ecosystem has been severely degraded. As a result, at least 18 species of mussels and 32 species of aquatic snails are presumed to have gone extinct, mostly within the past few decades. The Jackson, Mississippi field office of the U.S. Fish and Wildlife Service has initiated development of a recovery plan draft to address water quality improvement measures for the benefit of all federally listed aquatic flora and fauna in the Mobile River Basin. There are currently 32 aquatic animal and plant species in the basin that are listed under the ESA (U.S. Fish and Wildlife Service, 1994a). The primary objective of the plan under development is to protect the Basin's aquatic flora and fauna by achieving ecosystem stabilization. Actions presented in the draft plan to achieve this objective include the following:

- 1) Protection of habitat integrity and water quality by full and appropriate implementation of federal and state regulations.
- 2) Development and implementation of Best Management Practices and Water Quality Plans for construction, agriculture, urban, and suburban activities that affect aquatic ecosystems.
- 3) Development and implementation of Watershed Management Plans that address problems specific to watersheds occupied by listed species.
- 4) Development, funding, and implementation of programs that educate and directly involve the general public in ecosystem recovery.
- 5) Basic research on life history, ecology, anatomy, taxonomy, contaminant sensitivities, and propagation of listed and candidate species.
- 6) Reintroduction of listed and endemic species into restored habitats, as appropriate.
- 7) Monitoring of listed species populations.
- 8) Coordination of ecosystem and species recovery efforts.

Many of the needs and objectives of the Mobile River Basin Draft Recovery Plan are similar to those previously discussed for the southern Appalachian Mountains, including

stressing the need for public education and cooperation between government agencies and the private sector. Improvements in water quality have been made in the Mobile River Basin, in part due to government regulation. These regulations alone, however, can't provide adequate protection to the imperiled species of the Mobile River Basin. It has become obvious that the public will have to become directly involved if the flora and fauna of the Basin, including its imperiled amphibians, are to be protected. Government agencies can provide support through conservation agreements, on-site guidance and assistance, and funds for stream protection and restoration. Water quality problems can be addressed through federal government funded research and the development of alternative practices.

In addition to this cooperation, both private and public entities need to formulate strategies to improve water quality through local actions. Individuals and organizations will need to enlist support for programs at the local level and to encourage individual- and community-based responsibility for the protection of water resources. Organizations already in existence, such as The Nature Conservancy, Alabama Natural Heritage Program, River Watch, Adopt-a-Stream, and others, could take the lead in encouraging public involvement. Government sponsored projects such as the construction of impoundments, channelization, and dredging should require assessments of need and alternatives, and economic analyses including assessments of costs associated with environmental impacts. Federal agencies such as the COE and the EPA need to fulfill their obligations to maintain and improve water quality within the Basin.

Conservation and management strategies focused on imperiled amphibians should prioritize streams within the Mobile River Basin based on occurrences of rare fauna and potential for restoration. Drainage Management Plans could then be designed to implement stream restoration and species specific management. State and federal regulatory agencies should be encouraged to enforce current water quality and mining regulations within these drainages. Through a cooperative effort between the public and private sector, Best Management Practices should be developed to address nonpoint discharge and run-off within an ecosystem context.

### **Longleaf Pine Forest Ecosystem**

The longleaf pine forest ecosystem was once the predominant vegetative community of the southeastern Coastal Plain and stretched from Virginia to Texas (Means, 1988). Longleaf pine communities in pre-settlement times covered 60-80 million acres (roughly 24.3-32.4 million ha), over 60 percent of the upland area of the coastal plain (Croker, 1979; Ware et al., 1993). Today these communities cover less than 2 percent of their original distribution (Ware et al., 1993). The original longleaf pine stands ranged across a wide spectrum of environmental conditions from wet, poorly drained flatwoods to well-drained high pine or dry sandhills (Boyce and Martin, 1993). Urban development and conversion to agriculture have eliminated large portions of this ecosystem. Wetlands, integrated within the longleaf pine ecosystem, have been lost through ditching, draining, filling, and lowering of the water table. Intensive forestry has changed the once open longleaf pine stands to dense loblolly and slash pine plantations and second-growth hardwoods. Most of the longleaf pine ecosystem that remains is second-growth and degraded by logging, turpentine, grazing, intensive site preparation, and fire suppression (Noss, 1988).

The gopher frog, the striped newt, the flatwoods salamander, and two subspecies of dwarf siren (*Pseudobranchius striatus*) are imperiled amphibians endemic to longleaf pine

forests. An additional five imperiled amphibians, three salamander species and two frog species, would also benefit from protection of the longleaf pine habitat (Table 4).

Habitat changes in the longleaf pine ecosystem could have significant impacts on the distribution and abundance of imperiled amphibians. Grant et al. (1994) compared amphibian communities on even-aged pine plantations in South Carolina in four age-classes (one, three, eight, and 26 years). First-year pine plantations had the lowest species richness and the 26-year-old plantations had the highest. Enge and Marion (1986) examined the effects of clearcutting and site preparation on amphibian community dynamics in pine flatwoods forest in Florida. Clearcutting decreased reproductive success, reducing species abundance by a factor of ten. Means and Moler (1979) studied the imperiled Pine Barrens treefrog (*Hyla andersonii*) in seepage bogs in the Florida panhandle. They found that the seepage habitat could be destroyed by woody shrub succession resulting from fire suppression. Another study in Florida implicated the conversion of longleaf pine savannas to bedded slash pine plantations in the decline of a local flatwoods salamander population (Means et al., 1996). In a few cases, however, forestry practices such as clearcutting may mimic some natural processes. Campbell and Christman (1982) suggested that these techniques may substitute for the hot, lightning-ignited crown fires to which sand pine stands are adapted. Researchers studying amphibian populations within the longleaf pine ecosystem need to become familiar with current and past forest management practices (site preparation, regeneration method, rotation time, etc.) in different longleaf pine habitats (deMaynadier and Hunter, 1995). Studies can then be conducted to isolate and evaluate the impacts of various practices on imperiled amphibians and to provide information to land managers for use in development of resource management plans.

At present, imperiled amphibians are benefiting from protection afforded other species with which they share their terrestrial habitat (e.g., the federally threatened gopher tortoise and eastern indigo snake, and the endangered red-cockaded woodpecker). Maintenance of longleaf pine habitat for amphibians will also require wetlands conservation. The imperiled dwarf sirens are totally aquatic. The other imperiled longleaf pine species, except for the pine barrens tree frog, require temporary ponds in which to breed. The ponds required by these species are typically devoid of large predaceous fish and dry completely on a cyclic basis, generally during the summer months (Moler and Franz, 1987; LaClaire and Franz, 1991). These temporary ponds are very sensitive to changes in hydrology (LaClaire, 1992). In order to protect these sites, the practice of using the pond basins as recipient sites for road run-off or for slash disposal during timbering operations should be terminated. Bedding, ditching, and harvesting of hardwoods in pond basins should be curtailed whenever possible to maintain pond function (Vickers et al., 1985; Dodd and LaClaire, 1995). The hydrology of the area surrounding these ponds should not be altered, or the capacity of the basin to hold water may be compromised. In addition, fires should be allowed to burn completely across dry pond basins in order to maintain the wetland plant community necessary for nutrient cycling and amphibian egg attachment and larval development (LaClaire, 1995).

Most of the remaining acres of longleaf pine habitat are on private lands and are rapidly being converted to slash and loblolly pine or developed for residential or industrial use (Means and Grow, 1985). Efforts are being made by the U.S. Fish and Wildlife Service to assist the private timber industry in the formation of Habitat Conservation Plans which will allow for the needs of industrial forestry and for conservation of endangered species



**Table 4.** Imperiled amphibian fauna of the longleaf pine ecosystem. All = endemic, Part = part of range within longleaf pine ecosystem.

Taxon	All	Part
<b>SALAMANDERS</b>		
Ambystomatidae		
<i>Ambystoma cingulatum</i> , flatwoods salamander	X	
<i>A. talpoideum</i> , mole salamander		X
<i>A. tigrinum tigrinum</i> , tiger salamander		X
Salmandridae		
<i>Notophthalmus perstriatus</i> , striped newt	X	
Sirenidae		
<i>Pseudobranchius striatus spheniscus</i> , slender dwarf siren	X	
<i>P. s. striatus</i> , broad-striped dwarf siren	X	
<b>FROGS</b>		
Hylidae		
<i>Hyla andersonii</i> , Pine Barrens treefrog		X
<i>H. gratiosa</i> , barking treefrog		X
Ranidae		
<i>Rana capito</i> , gopher frog	X	

on industry lands. Public education programs are also underway in several states to demonstrate the benefits of planting and managing for longleaf pine to the small private landowner.

Primary obligation for protection of longleaf pine communities in public ownership rests with the U.S. Forest Service and the U.S. Department of Defense. The national forests of the Southeast contain about 700,000 acres (some 283,290 ha) of longleaf pine, representing one percent of the original longleaf pine community (Means and Grow, 1985). The DOD also has considerable acreage of longleaf pine habitat. For example, Eglin Air Force Base has 400,641 forested acres (about 162,140 ha) of which 81 percent are, or were historically, longleaf pine dominated sandhill communities (Department of Defense, 1993). The U.S. Forest Service and the DOD have re-oriented resource management programs toward an ecosystem-based approach.

To benefit imperiled amphibians, a longleaf pine ecosystem plan should include strategies for the following: re-establishing longleaf pine on appropriate sites; single tree selection timber harvesting to retain soil moisture; reducing soil disturbance during site preparation; maintaining the existing hydrology of temporary pond breeding sites; protecting streamside management zones; retaining downed logs, stumps, and snags as microhabitats; and using summer controlled burning (Means and Grow, 1985; Means, 1988; LaClaire, 1992; Dodd and LaClaire, 1995; Dupuis et al., 1995).

A region-wide plan is needed to protect the remaining longleaf pine ecosystem. A recent meeting hosted in 1994 by the U.S. Forest Service brought together a group of resource managers and researchers working in longleaf pine communities. This meeting highlighted the importance of a group effort to address protection and management of the remaining longleaf pine ecosystem. Development and coordination of a plan could be organized by working groups in each state. The working groups could then network with The Nature

Conservancy, the U.S. Forest Service, the U.S. Fish and Wildlife Service, state heritage programs, other state and federal agencies, and private timber companies which have an interest in the status of longleaf pine communities and rare and endangered species.

## CONCLUSIONS

There are 46 species of imperiled amphibians in the southeastern United States. Historically, resource management on public and private lands has not targeted amphibians, and their protection has been incidental to management for other resources. Recently, however, more emphasis has been placed on managing habitats and ecosystems which include imperiled amphibians.

There are many state and federal agencies and private conservation organizations that need to work together to implement resource management plans to conserve imperiled amphibians. Amphibian management in the Southeast will require status assessments, research, ecosystem management strategies (including long-term monitoring plans), and public participation to protect imperiled southeastern amphibians. Public involvement is crucial. Without the commitment of private landowners to conservation, amphibian management efforts can realize only minimal success. Legislation and regulations, no matter how worthwhile, will be effective only when the public perceives the good associated with them.

Most land available to imperiled amphibians in the Southeast is in private ownership. For example, timber companies own millions of acres that are often the only undeveloped sites large enough to maintain viable populations of amphibians and other wildlife. Increased efforts are needed to encourage conservation through mutual cooperation between the public and private sectors. As federal agencies, such as the U.S. Forest Service, the U.S. Fish and Wildlife Service, and others, shift from resource management to ecosystem management, rich opportunities for effective partnerships should develop. If these partnerships are nourished, they will provide tremendous opportunities to grow broad-based conservation support for imperiled amphibians as well as other plants and animals.

## REFERENCES

- Anderson, H. W., M. D. Hoover, and K. G. Reinhart. 1976. Forests and water: Effects of forest management on floods, sedimentation and water supply. General Technical Report PSW-GTR-18, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA, 118 p.
- Ash, A. N. 1988. Disappearance of salamanders from clearcut plots. *Journal of the Elisha Mitchell Science Society* 104:116-122.
- Ash, A. N. 1994. Disappearance and return of salamanders to clearcut plots in the southern Blue Ridge Mountains. In *Proceedings of the Fifth Annual Southern Appalachian Man and the Biosphere Conference*. (Abstracts). Hendersonville, NC, p. 13.
- Ash, A. N., and R. C. Bruce. 1994. Impacts of timber harvesting on salamanders. *Conservation Biology* 8:300-301.
- Bailey, M. A. 1992. Black Warrior waterdog status survey: Final report 1991-92. Unpublished Report submitted to the U.S. Fish and Wildlife Service, Atlanta, GA, 27 p.

- Bailey, M. A. 1995. Black Warrior waterdog survey, 1994-95. Unpublished Report submitted to the U.S. Fish and Wildlife Service, Atlanta, GA, 27 p.
- Blaustein, A. R., and D. B. Wake. 1990. Declining amphibian populations: A global phenomenon? *Trends in Ecology and Evolution* 5:203-204.
- Blaustein, A. R., D. B. Wake, and W. P. Sousa. 1994. Amphibian declines: Judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology* 8:60-71.
- Blumm, M. C., and D. B. Zaleha. 1989. Federal wetlands protection under the Clean Water Act: Regulatory ambivalence, intergovernmental tension, and a call for reform. *University of Colorado Law Review* 60:695-772.
- Bookhout, T. A. (ed.). 1994. *Research and Management Techniques for Wildlife and Habitat, 5th Edition*. The Wildlife Society, Bethesda, MD.
- Boyce, S. G., and W. H. Martin. 1993. The future of the terrestrial communities of the southeastern United States. In *Biodiversity of the Southeastern United States: Upland Terrestrial Communities*. W. H. Martin, S. G. Boyce, and A. D. Echternacht (eds.). John Wiley and Sons, Inc., New York, NY, p. 339-366.
- Campbell, H. W., and S. P. Christman. 1982. The herpetological components of Florida sandhill and sand pine scrub association. In *Herpetological Communities*. N. J. Scott, Jr. (ed.). Wildlife Research Report 13, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C., p. 163-171.
- Clark, T. W., R. P. Reading, and A. L. Clarke. 1994. *Endangered Species Recovery: Finding the Lessons, Improving the Process*. Island Press, Washington, D.C.
- Conant, R., and J. T. Collins. 1991. *A Field Guide to Reptiles and Amphibians of Eastern and Central North America*. Houghton Mifflin Company, Boston, MA.
- Corn, P. S., and R. B. Bury. 1990. Sampling methods for terrestrial amphibians and reptiles. General Technical Report PNW-GTR-256, Forest Service, U.S. Department of Agriculture, Portland, OR, 34 p.
- Crocker, T. C., Jr. 1979. The longleaf pine story. *Journal of Forestry History* 1979 (January):32-43.
- deMaynadier, P. G., and M. L. Hunter. 1995. The relationship between forest management and amphibian ecology: A review of the North American literature. *Environmental Review* 3:230-261.
- Department of Defense. 1993. Natural resources management plan, Eglin Air Force Base. U.S. Department of the Air Force, Eglin Air Force Base, FL, 235 p.
- Dodd, C. K., Jr. 1991. The status of the Red Hills salamander *Phaeognathus hubrichti*, Alabama, USA, 1976-1988. *Biological Conservation* 55:57-75.
- Dodd, C. K., Jr. 1993. Strategies for snake conservation. In *Snakes: Ecology and Behavior*. R. A. Seigel, and J. T. Collins (eds.). McGraw-Hill, Inc., New York, NY, p. 363-393.
- Dodd, C. K., Jr., and B. G. Charest. 1988. The herpetological community of temporary ponds in north Florida sandhills: Species composition, temporal use, and management implications. In *Management of Amphibians, Reptiles, and Small Mammals in North America*. R. E. Szaro, K. E. Severson, and D. R. Patton (eds.). General Technical Report RM-166, Forest Service, U.S. Department of Agriculture, Fort Collins, CO, p. 87-97.
- Dodd, C. K., Jr., and L. V. LaClaire. 1995. Biogeography and status of the striped newt (*Notophthalmus perstriatus*) in Georgia, USA. *Herpetological Natural History* 3:37-46.

- Doppelt, B., M. Scurlock, C. Frissell, and J. Karr. 1993. *Entering the Watershed*. Island Press, Washington, D.C.
- Duellman, W. E., and L. Trueb. 1986. *Biology of Amphibians*. McGraw-Hill Book Company, New York, NY.
- Dupuis, L. A., J. J. M. Smith, and F. Bunnell. 1995. Relation of terrestrial-breeding amphibian abundance to tree-stand age. *Conservation Biology* 9:645-653.
- Enge, K. M., and W. R. Marion. 1986. Effects of clearcutting and site preparation on herpetofauna of a north Florida flatwoods. *Forest Ecology Management* 14:177-192.
- Foley, D. H. 1994. Short-term response of herpetofauna to timber harvesting in conjunction with streamside management zones in seasonally-flooded bottomland-hardwood forests of southeast Texas. M.S. Thesis, Texas A&M University, College Station, TX.
- Franklin, J. E. 1989. Importance and justification of long-term studies in ecology. In *Long-term Studies in Ecology*. G. E. Likens (ed.). Springer Publishing Company, New York, NY, p. 3-19.
- Gibbons, J. W. 1988. The management of amphibians, reptiles and small mammals in North America: The need for an environmental attitude adjustment. In *Management of Amphibians, Reptiles, and Small Mammals in North America*. R. C. Szaro, K. E. Severson, and D. R. Patton (eds.). General Technical Report RM-166, Forest Service, U.S. Department of Agriculture, Fort Collins, CO, p. 4-10.
- Gibbons, J. W., and R. D. Semlitsch. 1991. *Guide to the Reptiles and Amphibians of the Savannah River Site*. The University of Georgia Press, Athens, GA.
- Grant, B. W., Brown, K. L., Ferguson, G. W., and J. W. Gibbons. 1994. Changes in amphibian biodiversity associated with 25 years of pine forest regeneration: Implications for biodiversity management. In *Biological Diversity: Problems and Challenges*. S. K. Majumdar, F. J. Brenner, J. E. Lovich, J. F. Schalles, and E. W. Miller (eds.). The Pennsylvania Academy of Science, Philadelphia, PA, p. 355-367.
- Hairston, M. G., Sr., and R. H. Wiley. 1993. No decline in salamander (Amphibia: Caudata) populations: A twenty-year study in the southern Appalachians. *Brimleyana* 18:59-64.
- Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L.-A. C. Hayek, and M. S. Foster. 1994. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington, D.C.
- Hipes, D., and D. Jackson. 1994. Rare vertebrate survey of Camp Blanding Training Site. Florida Natural Areas Inventory and The Nature Conservancy, Tallahassee, FL, 66 p.
- International Paper Timberlands Operating Company, Ltd. 1993. Red Hills salamander habitat conservation plan. U.S. Fish and Wildlife Service, Jackson, MS, 32 p.
- Jones, K. B. 1986. Amphibians and reptiles. In *Inventory and Monitoring of Wildlife Habitat*. A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart (eds.). Bureau of Land Management Service Center, U.S. Department of the Interior, Denver, CO, p. 267-290.
- Karr, J. R. 1990. Biological integrity and the goal of environmental legislation: Lessons for conservation biology. *Conservation Biology* 4:244-250.
- Kramer, P., N. Reichenbach, M. Hayslett, and P. Sattler. 1993. Population dynamics and conservation of the Peaks of Otter salamander, *Plethodon hubrichti*. *Journal of Herpetology* 27:431-435.

- LaClaire, L. V. 1992. Ecology of temporary ponds in north-central Florida. M.S. Thesis, University of Florida, Gainesville, FL.
- LaClaire, L. V. 1995. Vegetation of selected upland temporary ponds in north and north-central Florida. *Bulletin of the Florida Museum of Natural History* 38:69-96.
- LaClaire, L. V., and R. Franz. 1991. Importance of isolated wetlands in upland landscapes. In *Proceedings of the Second Annual Meeting*. M. Kelly (ed.). Florida Lake Management Society, Winter Haven, FL, p. 9-15.
- Livermore, B. 1992. Amphibian alarm: Just where have all the frogs gone? *Smithsonian Magazine* 1992(October):113-120.
- Livingston, R. J. 1992. Medium-sized rivers of the gulf coastal plain. In *Biodiversity of the Southeastern United States: Aquatic Communities*. C. T. Hackney, S. M. Adams, and W. H. Martin (eds.). John Wiley and Sons, New York, NY, p. 351-386.
- Master, L. L. 1991. Assessing threats and setting priorities for conservation. *Conservation Biology* 5:559-563.
- Means, D. B. 1988. Management recommendations for the gopher tortoise in the longleaf pine ecosystem. In *Gopher Tortoise Habitat Management: Strategies and Options*. C. K. Dodd, Jr. (ed.). Proceedings of the Sixth Annual Meeting of the Gopher Tortoise Council, Florida Museum of Natural History, Gainesville, FL, p. 41-56.
- Means, D. B., and G. Grow. 1985. The endangered longleaf pine community. ENFO Report, Environmental Information Center of the Florida Conservation Foundation, Inc., Winter Park, FL, 12 p.
- Means, D. B., and P. E. Moler. 1979. The pine barrens treefrog: Fire, seepage bogs, and management implications. In *Proceedings of the Rare and Endangered Wildlife Symposium*. R. R. Odum, and L. Langers (eds.). Technical Bulletin WL-4, Game and Fish Division, Georgia Department of Natural Resources, Atlanta, GA, 77-83.
- Means, D. B., J. G. Palis, and Mary Baggett. 1996. Effects of slash pine silviculture on a Florida population of flatwoods salamander. *Conservation Biology* 10:426-437.
- Millsap, B. A., J. A. Gore, D. E. Runde, and S. I. Cerulean. 1990. Setting priorities for the conservation of fish and wildlife species in Florida. *Wildlife Monographs* 111:1-57.
- Mitchell, J. C. 1994. Habitat conservation assessment for the Cow Knob salamander (*Plethodon punctatus*) in the George Washington National Forest. Report submitted to the U.S. Fish and Wildlife Service, Annapolis, MD, and the George Washington National Forest, Harrisonburg, VA, 16 p.
- Moler, P. E., and R. Franz. 1987. Wildlife values of small, isolated wetlands in the Southeastern Coastal Plain. In *Proceedings of the Third Southeastern Nongame and Endangered Wildlife Symposium*. R. R. Odom, K. A. Riddleberger, and J. C. Ozier (eds.). Georgia Department of Natural Resources, Atlanta, GA, p. 234-241.
- Natural Heritage Data Center Network. 1993. Perspectives on species imperilment, Revised printing. The Nature Conservancy, Arlington, VA, 40 p.
- Noss, R. F. 1988. The longleaf pine landscape of the Southeast: Almost gone and almost forgotten. *Endangered Species Update* 5:1-6.
- O'Connell, M. A., and R. F. Noss. 1992. Private land management for biodiversity conservation. *Environmental Management* 16:435-450.

- Palis, J. G. 1992. Distribution of the flatwoods salamander, *Ambystoma cingulatum*, on the Apalachicola and Osceola National Forests, Florida. Unpublished Report submitted to the Florida Natural Areas Inventory, Tallahassee, FL, 19 p.
- Palis, J. G. 1993. A status survey of the flatwoods salamander, *Ambystoma cingulatum*, in Florida. Unpublished Report submitted to the U.S. Fish and Wildlife Service, Jackson, MS, 36 p.
- Palis, J. G. 1995a. A survey of the flatwoods salamander (*Ambystoma cingulatum*) breeding sites east of the Apalachicola River, Florida. Unpublished Report submitted to the U.S. Fish and Wildlife Service, Jackson, MS, 40 p.
- Palis, J. G. 1995b. Distribution and breeding biology of the flatwoods salamander (*Ambystoma cingulatum*) and gopher frog (*Rana capito*) on Eglin Air Force Base, Florida. Florida Natural Areas Inventory, Tallahassee, FL, 46 p. + appendices.
- Pechmann, J. H. K., D. E. Scott, R. D. Semlitsch, J. P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: The problem of separating human impacts from natural fluctuations. *Science* 253:892-895.
- Pechmann, J. H. K., and H. M. Wilbur. 1994. Putting declining amphibian populations in perspective: Natural fluctuations and human impacts. *Herpetologica* 50:65-84.
- Petranka, J. W., M. E. Elridge, and K. E. Haley. 1993. Effects of timber harvesting on southern Appalachian salamanders. *Conservation Biology* 7:363-370.
- Phelps, J. P., and R. A. Lancia. 1995. Effects of a clearcut on the herpetofauna of a South Carolina bottomland swamp. *Brimleyana* 22:31-45.
- Raymond, L. R., and L. M. Hardy. 1991. Effects of a clearcut on a population of the mole salamander, *Ambystoma talpoideum*, in an adjacent unaltered forest. *Journal of Herpetology* 25:509-512.
- Schemnitz, S. D. (ed.). 1980. *Wildlife Management Techniques Manual*. The Wildlife Society, Washington, D.C.
- Scott, N. J., Jr., and R. A. Seigel. 1992. The management of amphibian and reptile populations: Species priorities and methodological and theoretical constraints. In *Wildlife 2001: Populations*. D. R. McCullough, and R. H. Barrett (eds.). Elsevier Applied Science, New York, NY, p. 343-367.
- Sedell, J. R., G. H. Reeves, R. R. Hauer, J. A. Stanford, and C. P. Hawkins. 1990. Role of refugia in recovery from disturbances: Modern fragmented and disconnected river systems. *Environmental Management* 14:711-724.
- Seehorn, M. E. 1982. Reptiles and amphibians of southeastern national forests. Forest Service, U.S. Department of Agriculture, Atlanta, GA, 84 p.
- Stiven, A. E., and R. C. Bruce. 1988. Ecological genetics of the salamander *Desmognathus quadramaculatus* from disturbed watersheds in the Southern Appalachian Biosphere Reserve Cluster. *Conservation Biology* 2:194-205.
- Szaro, R. E., K. E. Severson, and D. R. Patton (eds.). 1988. *Management of Amphibians, Reptiles, and Small Mammals in North America*. General Technical Report RM-166, Forest Service, U.S. Department of Agriculture, Fort Collins, CO, 458 p.
- Telford, S. 1993. Breeding sites for the gopher frog and the striped newt in the Ocala National Forest, and the discovery of a possibly undescribed species of frog apparently restricted to the forest. Unpublished Report submitted to staff at Ocala National Forest, Ocala, FL, 29 p.



- The Nature Conservancy and the International Network of Natural Heritage Programs and Conservation Data Centers. 1996. Biological and conservation databases. The Nature Conservancy, Arlington, VA, 58 p.
- Underwood, A. J. 1995. Ecological research and (research into) environmental management. *Ecological Applications* 5:232-247.
- U.S. Fish and Wildlife Service. 1994a. Endangered and threatened wildlife and plants. 50 CFR 17.11 and 17.12. U.S. Government Printing Office, Washington, D.C., 42 p.
- U.S. Fish and Wildlife Service. 1994b. Endangered and threatened wildlife and plants: Animal candidate review for listing as endangered or threatened species, proposed rule. *U.S. Federal Register* 59 CFR, Part 17, 59(219):58982-59028.
- U.S. Fish and Wildlife Service. 1995. Ecosystem management plan for the southern Appalachian ecosystem. Asheville Field Office, U.S. Fish and Wildlife Service, Asheville, NC, 15 p.
- U.S. Fish and Wildlife Service. 1996. Endangered and threatened species, plant and animal taxa; proposed rule. *U.S. Federal Register* 50 CFR, Part 17, 61(40):7596-7613.
- Vial, J. L., and L. Saylor. 1993. The status of amphibian populations: A compilation and analysis. Working Document Number 1, IUCN/SSC Declining Amphibian Populations Task Force, Corvallis, OR, 98 p.
- Vickers, C. R., L. D. Harris, and B. F. Swindel. 1985. Changes in herpetofauna resulting from ditching of cypress ponds in coastal plains. *Forest Ecology Management* 11:17-29.
- Vitt, L. J., J. P. Caldwell, H. M. Wilbur, and D. C. Smith. 1990. Amphibians as harbingers of decay. *BioScience* 40:418.
- Wallace, J. B., J. R. Webster, and R. L. Lowe. 1992. High-gradient streams of the Appalachians. In *Biodiversity of the Southeastern United States: Aquatic Communities*. C. T. Hackney, S. M. Adams, and W. H. Martin (eds.). John Wiley and Sons, New York, NY, p. 133-192.
- Ware, S., C. Frost, and P. D. Doerr. 1993. Southern mixed hardwood forest: The former longleaf pine forest. In *Biodiversity of the Southeastern United States: Lowland Terrestrial Communities*. W. H. Martin, S. G. Boyce, and A. C. Echternacht (eds.). John Wiley and Sons, New York, NY, p. 447-493.
- Yoffe, E. 1992. Silence of the frogs. *New York Times Magazine* 1992(December 13):36-39, 64, 66, 76.

**DISTRIBUTION AND BREEDING BIOLOGY OF THE  
FLATWOODS SALAMANDER (AMBYSTOMA CINGULATUM)  
AND GOPHER FROG (RANA CAPITO) ON EGLIN AIR  
FORCE BASE, FLORIDA.**

**FINAL REPORT**

Report Prepared by  
John G. Palis, Principal Investigator

Breeding Site Descriptions Prepared by  
John B. Jensen, Field Zoologist

Dale R. Jackson, Project Supervisor

Florida Natural Areas Inventory  
1018 Thomasville Road, Suite 200-C  
Tallahassee, FL 32303

30 September 1995

Cover photographs taken by John Palis.

## ABSTRACT

Eglin Air Force Base (AFB), Florida, was surveyed for two rare amphibians, the gopher frog (Rana capito) and the flatwoods salamander (Ambystoma cingulatum), for the majority of three consecutive breeding/larval seasons beginning in January 1993. Gopher frog reproduction was confirmed in 26 wetlands, including 23 previously undocumented sites. These sightings are thought to represent 13 breeding populations. Flatwoods salamander reproduction was confirmed in 25 wetlands, constituting the first observations of the species on Eglin AFB. Three flatwoods salamander breeding populations -- consisting of one, three and 21 breeding sites -- are believed to occur on Eglin AFB. Because of annual variations in hydroperiod, multi-year surveys are especially important in determining the presence or absence of these species.

Flatwoods salamander movement into and away from a known breeding site was monitored with a drift fence and funnel traps for 6 months during the 1993-1994 breeding season and 7.5 months during the 1994-1995 breeding season. During the 1993-1994 breeding season, the fence intercepted 198 salamanders, 76% in the months of October and November; yearlings comprised 65.5% of the catch. A total of 59 salamanders was captured in 1994-1995, only 10% of which were yearlings. Salamander movement was positively correlated with precipitation and minimum air temperature. In 1993-1994, salamanders that entered and exited the basin only once remained in the basin an average of 38 days and exited within an average of 44 m (4 traps) from the point of entry. More salamanders immigrated from longleaf/slash pine mesic flatwoods than from longleaf/sand pine scrubby flatwoods.

Gopher frog movement at a known breeding site was monitored for 7 months with a drift fence and pitfall traps during the 1994-1995 breeding season. A total of 297 adults and 31 metamorphs was captured at the drift fence. Most adults (51%) were captured in February, but metamorphs were not observed until May. An undetermined number of frogs bred in October prior to the emplacement of the drift fence. Gopher frog movement was positively correlated with rainfall and warm air temperatures. Frogs that entered and exited the basin only once remained in the basin an average of 11.6 days and exited within an average of 40 m (4 traps) from the point of entry. A total of 159 egg masses were observed, deposited an average of 3.94 cm below the surface and 2.79 m apart. Egg masses were laid in water 17 - 78 cm deep and from 7 - 71 cm above the pond floor. Egg masses contained an average of 2210 eggs. Each female lays one egg mass (presumably annually), providing a means of estimating the size of the female breeding population.

Eglin AFB supports the largest known concentration of reproductive sites of the dusky gopher frog, Rana capito sevosa, anywhere within its range, and the largest known concentration of flatwoods salamander breeding sites west of the Apalachicola River. Every effort should be made to maintain and enhance these populations. Management recommendations toward that goal include an accelerated program of prescribed burning, particularly during the lightning-season; removal of off-site pine species, followed by re-

establishment of longleaf pine and associated native groundcover; and protection of all breeding sites and adjacent uplands (to 2 km) from further disturbance. Efforts to increase the population of gopher tortoises by habitat management and protection from poaching are important in maintaining a healthy gopher frog population, as tortoise burrows provide shelter for this rare amphibian.

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- IV: Survey dates and observations of flatwoods salamander breeding activity at reproductive sites surveyed from 1993 - 1995 on Eglin AFB, Florida



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## INTRODUCTION

In 1985, Paul Moler of the Florida Game and Fresh Water Fish Commission (GFC) first documented the existence of the dusky gopher frog (Rana capito sevosa) on Eglin Air Force Base (AFB) in western Florida. Additional observations were made at two sites in 1988 and 1989 by Karl R. Studenroth, Jr., then stationed at Eglin AFB while enlisted in the U.S. Air Force. Biologists with the U.S. Fish and Wildlife Service (USFWS), Florida Natural Areas Inventory (FNAI), and GFC visited known gopher frog breeding sites during February 1992 and found evidence of gopher frog reproduction at one of the three known sites.

As seemingly suitable gopher frog habitat exists on much of Eglin AFB, the FNAI submitted a proposal to the U.S. Department of Defense to survey the base for gopher frogs, as well as for the flatwoods salamander (Ambystoma cingulatum). Although the flatwoods salamander was not known from Eglin, its presence was suspected based on the presence of suitable habitat. Eglin AFB was surveyed for gopher frogs and flatwoods salamanders for the majority of three consecutive breeding/larval seasons: 18 January - 8 April 1993, 15 September 1993 - 15 May 1994, and 3 October 1994 - 31 May 1995.

Gopher frogs and flatwoods salamanders are perceived to be declining throughout much of their ranges, although information regarding their present distributions is inadequate. During the first and second years of this survey, field work consisted principally of locating breeding sites of both species on Eglin AFB. In addition, the movement of migrating flatwoods salamanders was monitored during the second field season at a known breeding site, EG-40, using a combination of a drift fence and funnel traps. During the final year of the survey, the emphasis shifted from breeding site assessment to drift fence monitoring. In addition to continued monitoring of the movement of salamanders at EG-40, the migration of gopher frogs was studied at Holley Pond using the drift fence technique. This report summarizes the findings of the three-year field investigation.

### Life History Summaries

#### Gopher Frog

The gopher frog inhabits xeric upland pine communities of the Southeastern Coastal Plain, from southeastern Louisiana to southeastern North Carolina (Conant and Collins, 1991). The subspecies sevosa (dusky gopher frog) is thought to occur west of the Choctawhatchee River (Conant and Collins, 1991). Post-larval gopher frogs are terrestrial and inhabit the relatively cool, moist tunnels of burrowing animals such as the gopher tortoise (Gopherus polyphemus) and oldfield mouse (Peromyscus polionotus) (Gentry and Smith, 1968; Lee, 1968; Franz, 1986). Gopher frogs also take shelter within hollow stumps and in holes beneath logs, trees and stumps (Wright and Wright, 1949). The species is generally nocturnal and can sometimes be observed at the mouths of tortoise burrows. According to Wright and Wright (1949), gopher frogs will range "some distance from their burrows in foraging at night." Activity outside the burrow is not confined exclusively to dark periods, however, as gopher frogs have been observed foraging on the surface during the day (Einem and Ober, 1956).

Gopher frogs breed in ephemeral or semi-permanent graminoid-dominated ponds that lack large predatory fish (Bailey, 1991; Palis, pers. obs.). At the latitude of panhandle Florida, gopher frogs typically reproduce in the winter and early spring, from January through April (Bailey, 1991; Palis, pers. obs.). However, Bailey (1991) also observed reproduction in southern Alabama in September and October following heavy rains associated with hurricanes, and Wright (1931) observed reproduction in July and August in the Okefenokee Swamp, Georgia. The call of the gopher frog is a loud snore that may last up to two seconds (Wright and Wright, 1933). Gopher frogs may also call while submerged beneath the water's surface, which significantly mutes the call (Jensen et al., 1995). Gopher frogs have been documented moving as far as 2 km between reproductive and non-reproductive habitats (Franz et al., 1988).

The fist-sized, globular or U-shaped egg masses of gopher frogs are generally attached to the vertical stems of emergent herbaceous vegetation, but inundated limbs of shrubs or trees, such as Hypericum spp. (St. John's-wort) or Ilex myrtifolia (myrtle-leaved holley), are also used (Palis, pers. obs.; M. Bailey, pers. comm.). Occasionally egg masses are deposited, unattached, on the pond floor (Wright, 1931; M. Bailey, pers. comm.). Although egg masses may contain up to 6000 eggs (Volpe, 1958), they typically contain fewer than 2500 eggs (Bailey, 1990; A. Braswell, pers. comm.). The eggs of the gopher frog are readily distinguished from those of its congener, Rana sphenoccephala (southern leopard frog), by the larger size of the former (mean of 3.3 mm versus 2.2 mm in diameter; Palis, pers. obs.). The larvae attain lengths of up to 84 mm and metamorphose in approximately 10 - 14 weeks (Wright and Wright, 1949).

#### Flatwoods Salamander

The flatwoods salamander inhabits low, wet pine flatwoods and savannas from extreme southwestern Alabama eastward to south-central Florida and northward to southern South Carolina (Conant and Collins, 1991). Adults and subadults are fossorial and inhabit subterranean burrows (Mount, 1975).

Rains associated with autumnal cold fronts stimulate migration of adults to reproductive sites (Means, 1972). Reproduction occurs between early October and January (Means, 1972; Anderson and Williamson, 1976; Ashton, 1992; Palis, pers. obs.) in pine flatwoods depressions, including cypress- or blackgum-dominated swamps and roadside ditches (Palis, pers. obs.). Females lay up to 225 eggs (Ashton 1992) deposited singly or in small groups on the ground beneath leaf litter, under logs and Sphagnum mats, at the bases of grasses, shrubs or trees, or at the entrance to crayfish burrows (Anderson and Williamson, 1976). Eggs are laid terrestrially before depressions fill with water, and hatch upon inundation (Anderson and Williamson, 1976). The larvae attain total lengths of 96 mm and transform in 11 - 18 weeks (Palis, in press). Adults have been tracked moving as far as 1.7 km from their breeding site (Ashton, 1992).

#### Status

The gopher frog and flatwoods salamander both are Category 2 candidates for listing by the USFWS. Category 2 candidates are those for which there is some evidence of

vulnerability but for which insufficient data exist to support listing. The gopher frog is also listed in Florida as a Species of Special Concern by the GFC (Wood, 1992). Both species are threatened by habitat loss associated with agriculture, silviculture and real estate development (Godley, 1992; Means et al., in press).

## MATERIALS AND METHODS

### Distributional Surveys

Prior to the initiation of field work, potential gopher frog and flatwoods salamander habitat was delineated from 7.5 minute U.S. Geological Survey (USGS) topographic maps, blue-line aerial photographs, and U.S.D.A. Soil Conservation Service (USSCS) county soil surveys. Fifty-nine potential gopher frog breeding sites and 13 areas of potentially suitable flatwoods salamander adult/larval habitat were identified (Appendices I - IV). Sixteen additional potential gopher frog breeding sites and one additional area of potential flatwoods salamander habitat were identified from road reconnaissance and color aerial photographs after initiation of field work.

Gopher frog occurrence was determined principally from the presence or absence of egg masses during diurnal wading surveys of known and potential breeding sites. Investigators slowly waded at various depths and examined vegetation to which egg masses are commonly attached. At present, there is not a reliable non-destructive means of distinguishing gopher frog and leopard frog larvae. Egg mass surveys were supplemented with limited nocturnal vocalization surveys (i.e., listening for calling males) and road-cruising during weather conditions conducive to frog reproductive activity and movement.

Presence or absence of flatwoods salamanders was determined principally by dipnetting known and potential breeding sites for aquatic larvae. Larval surveys were supplemented with drift fences and funnel traps during Year 2. A 4-mm mesh nylon dipnet, manufactured by Mid-Lakes Corporation, Knoxville, Tennessee (net no. SH-2), was utilized for sampling. The nearly circular hoop of the net is 40.6 cm wide and 45.7 cm long. To standardize the effort made at each sampling site, each meter-long sweep was tallied as one sweep. The net was forced through inundated herbaceous vegetation, within which larval flatwoods salamanders take refuge during daylight hours (Palis, pers. obs.). The net was swept back and forth in a Z or S pattern, which effectively stirred up the water, vegetation and bottom debris. The net was also swept through vegetation following its agitation by foot in the direction of the net. Larvae were measured to the nearest 0.5 mm (total length and/or snout-vent length: tip of snout to posterior end of vent).

The following environmental variables were recorded at each site: water depth (measured with a meter stick where feasible, visually estimated at deeper gopher frog sites), water temperature (measured with a pocket thermometer), and pH (measured with a Hanna pocket pH meter calibrated at a temperature near ambient). Vegetation of the pond overstory, midstory and groundcover (i.e., substrate) was recorded at the most readily identifiable taxonomic level. In addition, descriptive notes of the surrounding terrestrial habitat were taken. Other amphibians, reptiles, fishes, and macroinvertebrates encountered

were identified at the most readily identifiable taxonomic level. Soils of surrounding uplands were determined from USSCS county soil surveys. The locations of all ponds visited were plotted onto USGS 7.5 minute topographic maps.

The determination of the presence or absence of flatwoods salamanders or gopher frogs was conducted principally during the first two years of the survey. Breeding site surveys were conducted almost daily from 18 January through 8 April 1993, and irregularly from 9 November 1993 through 10 May 1994. Drift fence monitoring permitted only limited surveys during Year 3. Gopher frog surveys were conducted after requisite rains stimulated gopher frog reproduction. Flatwoods salamander surveys generally were performed a month or more after known and potential breeding sites filled to allow larvae to reach a readily sampled size.

Presence or absence of flatwoods salamanders in the Fort Walton Beach Savanna was determined with a 15.25-m long x 0.9-m high drift fence erected near EG-50 and EG-51 (see Appendix VIII, EOR 67), approximately 100 m NW of RR 655, 0.08 km SW of RR 655/RR 636 junction, on 18 October 1993. The fence, constructed of silt fencing, was supported by wooden stakes. The bottom 10-15 cm of the fence were buried in the soil to prevent salamanders from crawling beneath it. Three pairs of aluminum window screen funnel traps were laid flush against the fence approximately 5 m apart. The traps were examined 11 of the 12 days that they were in place. The fence was removed on 30 October 1993.

Presence or absence of flatwoods salamanders in the relatively open slash pine savanna of Whitmier Island was investigated with a 15.25-m long x 0.9-m high silt fencing drift fence. The fence was erected near EG-01 (see Appendix II), about 150 m NW of RR 717, 1.2 km N of RR 211, on 20 October 1993. The bottom 10-15 cm of the fence were buried in the soil, and the above-ground portion was supported by wooden stakes. Initially, three pairs of 1.35-l pitfall traps were set adjacent to the fence approximately 5 m apart. However, when the traps were first checked on 22 October, they were full of water. The pitfalls were replaced with aluminum window screen funnel traps on 25 October. These funnel traps were set prior to predicted rain and examined periodically through 21 December, at which time the fence was removed.

#### Larval Studies

During Year 1 of the survey, I attempted to discern the distinguishing characteristics of larval gopher frogs and leopard frogs by studying larvae raised in situ. Two cages, each approximately 0.9 m square, were constructed of aluminum window screen and 3.8 cm by 1.6 cm lumber. The cages were placed in Holley Pond. This pond was chosen because it is used by both species for reproduction, occurs in relatively close proximity to the Okaloosa Tower office, and is protected from human disturbance by its location in a restricted area. One egg mass of each species was collected in Holley Pond and placed into a separate cage. Algal masses were periodically added to the cages as food for the larvae. Larvae were periodically examined as they developed.

During Year 2, an attempt was made to locate flatwoods salamander egg deposition sites at known flatwoods salamander breeding site EG-40 by sampling twenty-five randomly

generated plots for hatchling larvae. Sampling was conducted on 23 December 1993, two days after EG-40 filled to two-thirds capacity. Each sample plot was enclosed within a 0.17-m<sup>2</sup> box trap constructed of four 41-cm-square pieces of masonite. The box, open at the top and bottom, was lowered vertically into the water to the pond floor. The area encompassed by the box trap was sampled with ten sweeps of a 13.5-cm wide x 10-cm long, 0.5-mm mesh dipnet.

### Gopher Frog Egg Mass Deposition Study

Egg mass surveys were conducted in Holley Pond following each period of gravid frog immigration during the 1994 - 1995 breeding season. The location of each egg mass was marked with survey flags. The following data were recorded for each egg mass: plant species to which the egg mass was attached, maximum water depth (cm), egg mass distance below the surface (cm) and above the substrate (cm), and distance to the nearest egg mass (m). To determine whether frogs were choosing particular plant species as egg deposition sites or simply depositing eggs on vegetation in proportion to its availability, plant species identified at 100 randomly chosen points in October, February and April were compared with vegetation selected by gopher frogs.

Clutch size was determined by volumetric displacement of egg masses (Davis and Folkerts, 1986). Volumetric displacement was obtained by placing an egg mass into a 1-l graduated cylinder containing a known volume of water. The volume of water displaced by each egg mass was recorded and then multiplied by a standard displacement volume, previously determined by counting the number of eggs necessary to displace one ml of water in a 100-ml graduated cylinder.

### Breeding Migration Monitoring Studies

#### EG-40

The flatwoods salamander breeding population at a known reproductive site, EG-40, was monitored from 9 October 1993 through 31 March 1994, and from 27 October 1994 through 19 May 1995, with a combination of a drift fence and funnel traps. This site is located in the southwestern portion of the base, between the East Bay River and U.S. highway 98 (see Appendix VIII, EOR 65). It is surrounded on two sides by an open-canopied, mature longleaf/slash pine mesic flatwoods, and on the south-southwest side by a dry ridge that supports xeric longleaf pine/sand pine scrubby flatwoods (see Appendix VI for more detailed description).

To facilitate initial emplacement of the fence and provide an adjacent unobstructed zone for the placement of traps, a 0.6-m-wide path was cut completely around the pond through the grass-dominated ecotone with mechanical weed-eaters. A mechanical trencher was then employed to excavate a 20-cm deep, 10-cm wide trench in the middle of the cleared path. The drift fence was constructed from 15 m-long x 61-cm high rolls of aluminum flashing, the bottoms of which were buried in the trench to a depth of ca. 20 cm to prevent salamanders from crawling beneath the fence. Wooden stakes were used to support the fence, and the ends of adjoining rolls were overlapped and secured with duct tape. During



Doty (1972). The observed mean was significantly different from the mean generated if departure were random ( $t = 8.23$ ,  $p < .0001$ ). Nearly 38% of the salamanders exited within 11 m (one trap) of their entry point, and almost half (48%) departed within 22 m (two traps) of their point of arrival. There is no significant difference in the mean number of traps between entry and exit points for males and females ( $t = 1.34$ ,  $p = .18$ ), or between yearlings and sexually mature animals ( $t = .09$ ,  $p = .93$ ). The tendency to emigrate in the direction of immigration suggests that the flatwoods salamanders possess the ability to home to and from a particular terrestrial retreat. Similar observations have been made with congeneric Ambystoma opacum (Shoop and Doty, 1972; Stenhouse, 1985), A. maculatum (Phillips and Sexton, 1985), and A. talpoideum (Semlitsch, 1981).

I used the 85 salamanders that entered and exited the basin only once during the 1993 - 1994 breeding season to examine whether salamanders immigrated randomly with respect to surrounding terrestrial habitat. If salamanders inhabit the surrounding habitat randomly, the number of salamanders entering the basin from any particular point should be proportional to the number of traps facing that habitat. For example, since 32% of the traps lie along the southern perimeter of the basin, then 32% of the salamanders should enter from the south if movement with respect to habitat is random. A comparison of the expected immigration frequencies with those observed indicate that immigration is not random ( $X^2 = 13.07$ ,  $df = 3$ ,  $p < .005$ ). A greater proportion of salamanders entered from the open-canopied mesic longleaf pine-wiregrass and longleaf/slash pine-wiregrass flatwoods occurring east, north and northwest of the pond than would be expected by chance. Fewer salamanders than expected entered from the longleaf/sand pine scrubby flatwoods to the south and southwest.

### *Associated Species*

Table 2 lists 43 vertebrate species -- including 15 amphibians, 24 reptiles, three birds and one small mammal -- that were observed at the EG-40 drift fence. The dwarf salamander (Eurycea quadridigitata) was the most abundant species, with 2033 captures during the 1993-94 season and 1320 during 1994-95 season (because animals were not marked, this figure undoubtedly includes recaptures). A small number ( $< 2$  dozen) of these dwarf salamanders are members of an undescribed species first collected in southern Mississippi by Dr. Richard Highton of the University of Maryland (R. Highton, pers. comm.). The undescribed Eurycea is morphologically (underside of tail is yellow) and biochemically distinct from Eurycea quadridigitata. In addition, its breeding season begins as the breeding season of Eurycea quadridigitata ends (J. Jensen, pers. comm.). EG-40 is the only known site where Eurycea sp. and Eurycea quadridigitata occur sympatrically (R. Highton, pers. comm.).

## MANAGEMENT RECOMMENDATIONS

Although the gopher frog and flatwoods salamander inhabit different community types -- sandhill and pine flatwoods/savanna, respectively -- they share several habitat requirements. Both species inhabit open, longleaf pine-dominated forests with a diverse groundcover assemblage of grasses and forbs. The open canopy and herbaceous groundcover component of these communities is maintained by frequent fire (Myers and Ewel, 1990). In

addition, both species reproduce in wetlands that frequently dry and periodically burn (Myers and Ewel, 1990). Below I discuss species-specific recommendations for management of habitats utilized by these two species.

### Gopher Frog

Threats to the continued existence of the gopher frog are closely linked to those that threaten the gopher tortoise (Bailey, 1991; Godley, 1992) and probably the oldfield mouse. Since gopher frogs most often use gopher tortoise burrows as diurnal retreats (Godley, 1992) management that benefits the gopher tortoise will, in turn, benefit the gopher frog. The greatest current threats to gopher tortoises on Eglin AFB are fire suppression and conversion of the open, longleaf pine sandhill community to dense monocultures of sand pine, although poaching of random individuals may continue to suppress the species' recovery. Tortoise population density can decline as much as 80% when fire is excluded for eight or more years (Diemer, 1989). Because gopher tortoise densities are linked with the availability of forage (forbs and grasses) (Diemer, 1989), reduction of groundcover vegetation as a result of shading by closed-canopy sand pine plantations or leaf litter accumulation due to fire suppression can depress gopher tortoise numbers. Because the oldfield mouse also occurs in open, graminoid-dominated habitats (Burt and Grossenheider, 1976), its numbers would also likely decrease with a reduction in the groundcover. Existing efforts to re-introduce fire into the sandhill community on Eglin AFB should continue and be expanded. The area within a 2-km radius of each gopher frog breeding site should be a priority for periodic burning. Seasonality of fire is an important consideration in a prescribed fire plan. Historically, fire was ignited by lightning, most often between May and September (Robbins and Myers, 1992). Many components of the groundcover flora, such as wiregrass, only flower after lightning-season fire (Robbins and Myers, 1992). Furthermore, lightning-season fires are outside the reproductive period of gopher frogs and thus would not interfere with the species' movements to and from breeding sites.

Lightning-season fire may also be important to the maintenance of larval gopher frog habitat. Wetlands used by gopher frogs for reproduction are typically dry or partially dry during the lightning season. A fire passing through these sites when dry would consume herbaceous vegetation and possibly kill woody vegetation. Elimination or suppression of woody vegetation is important in maintaining the open, graminaceous character typical of most gopher frog breeding ponds. In addition, fire releases nutrients bound in plant material. This release of nutrients results in a flush of primary productivity that would be available to herbivorous gopher frog tadpoles the following winter. Because long-term maintenance of the terrestrial and aquatic habitat of the gopher frog is contingent upon lightning-season fire, it is recommended that prescribed fire be set during the lightning season whenever feasible.

Human consumption of gopher tortoises on Eglin AFB allegedly continues to occur despite the species' protected status. Although the infrequent removal of a tortoise for consumption is unlikely to impact a large tortoise colony adversely, sustained harvest over a long period could have a serious impact (Diemer, 1989). Despite the availability of apparently suitable habitat, gopher tortoise numbers on Eglin AFB appear to be extremely low. Efforts to thwart human predation of gopher tortoises on Eglin AFB should be

**enhanced.** Posters, bulletins, and lectures can be used to educate both military and non-military users of the base regarding the plight and protected statuses of the tortoise and its burrow commensals (including the federally listed eastern indigo snake).

Thirteen (50%) of the 26 known gopher frog breeding sites on Eglin AFB (EG-7, 8, 9, 10, 11, 19, 26, 27, 28, 30, 35, 99 and 103) have been disturbed by vehicular traffic. Ponds EG-7, 10, 30, 35 and 99 exhibit signs of ORV usage; ponds EG-8, 9, 27, 28 and 103 have roads that pass along the edge or through the center; and ponds EG-11, 19, and 26 contain roads and are disturbed by ORV usage. As discussed above (see Results), vehicular damage to gopher frog breeding sites may render them unsuitable for gopher frog reproduction. **Vehicular usage within 50 m of upland wetland depressions, particularly known gopher frog breeding sites, should be prohibited or restricted to emergency and natural resource enhancement functions only. Roads still open that pass along or through wetlands should be closed or re-routed.**

#### Flatwoods Salamander

The greatest threats to the long-term existence of the flatwoods salamander on Eglin AFB appear to be fire suppression and silvicultural activities such as clearcutting, mechanical site preparation and replacement of longleaf pine with slash or sand pine. As discussed above, lightning-ignited fires most often occur between May and September. This is outside the above-ground activity period of the post-larval life stages of the flatwoods salamander. Therefore, **re-introduction of fire into the habitat of the flatwoods salamander on Eglin AFB should be slated for the lightning-season whenever feasible.** However, to prevent a catastrophic fire, a fuel-reduction winter fire may be necessary before re-introducing lightning-season fire. Because lightning-season fire is more damaging to fire-intolerant shrubs than is winter fire (Robbins and Myers, 1992), lightning-season fire will better control the shrubs that are encroaching into the herbaceous wetland/upland ecotones and overtaking the breeding ponds. Control of shrubby vegetation in the breeding ponds is particularly important, since this vegetation often forms a dense subcanopy that can shade out the inundated herbaceous vegetation within which larval flatwoods salamanders take refuge during the day.

Circumstantial evidence suggests that local flatwoods salamander populations are extirpated as native terrestrial groundcover is lost (Means et al., in press). Groundcover vegetation can be lost through mechanical site preparation of the soil, herbicide application, fire suppression, rutting and compaction associated with timber harvest during wet periods, or a combination of these perturbations. Because flatwoods salamanders have been tracked moving as far as 1.7 km from a breeding site (Ashton, 1992), **every effort should be made to minimize soil disturbance within at least 2 km of known breeding sites. Clearcutting, and the associated use of mechanical site preparation and artificial planting of trees at densities higher than found in nature, should be replaced with selective timber harvest and natural regeneration enhanced by fire, particularly lightning-season fire.** Tree harvest should be restricted to dry periods to reduce disruption of the soil. Young off-site slash pine and sand pine should be removed in a manner least disruptive to the soil. This could be accomplished with prescribed fire or, on more xeric soils, bush-hogging during dry periods. Longleaf pine should then be planted at densities mimicking those found in

naturally regenerating stands on similar soils. When necessary, an effort should be made to re-seed these disturbed areas with native groundcover species that are not known to re-colonize areas once eliminated (e.g., wiregrass). Propagules of desired species should be collected from plants growing locally on the same soils.

The wetland/upland ecotone surrounding flatwoods salamander breeding sites may be critical to successful reproduction by this species. The capture of larvae in EG-40 only after inundation of the ecotone suggests that the herbaceous edge is the site of egg deposition. In addition, larger larvae often utilize the pond edge for refuge and probably for foraging. The ecotone of several breeding sites on Eglin AFB has been degraded by the emplacement of plow lines. One pond in particular, EG-65, is partially encircled by four parallel plow lines. Although most observed plow lines appear to be relatively old, I did note very recent lines laid adjacent to and through flatwoods salamander breeding site EG-02. Every effort should be made to minimize disturbance of flatwoods salamander habitat from plow lines. Under no circumstances should ponds or pond ecotones be disrupted with new plow lines. The extensive road system in the area provides ample fire breaks for the containment of prescribed and wild fires. In addition, other means of containing fires, such as black lines or back fires, should be used in place of soil-disrupting plow lines.

## SUMMARY OF MANAGEMENT RECOMMENDATIONS

### Gopher Frog

1. The terrestrial habitat within a 2-km radius of each breeding site should be prioritized for prescribed fire, particularly during the lightning season.
2. Efforts to prevent human predation of gopher tortoises should be enhanced through education of military and non-military users of the base.
3. Vehicular usage within 50 m of upland wetland depressions should be prohibited. Continue to close or re-route existing and new user-created roads that pass through or along the edge of upland depressions, particularly known breeding sites.
4. Restore native longleaf pine sandhill community lost or degraded by mechanical soil disturbance and establishment of off-site pine species within a 2-km radius of each breeding site.

### Flatwoods Salamander

1. The terrestrial habitat within a 2-km radius of each breeding site should be a priority for prescribed fire, particularly during the lightning season.
2. Minimize soil disturbance of breeding sites and terrestrial habitat within a 2-km radius of each breeding site.
3. Replace clearcutting of timber with selective forms of harvest.

4. Restore native longleaf pine flatwoods/savanna communities lost or degraded to mechanical soil disturbance and establishment of off-site pine species within a 2-km radius of each breeding site.

### MONITORING AND RESEARCH NEEDS

Much remains to be learned about the natural histories and management needs of the gopher frog and flatwoods salamander. Demographic data are sorely needed to responsibly manage the remaining populations of these rare species. Eglin AFB provides the ideal outdoor laboratory in which demographic studies can be performed. Knowledge gained on Eglin will provide important management direction for both species rangewide. Specific studies should focus on the following:

1. Re-sample known gopher frog and flatwoods salamander breeding sites annually for evidence of reproduction.
2. Establish long-term ( $\geq 10$  years) studies of demography of both species using the drift fence method.
3. Examine use of terrestrial habitat by both species with tracking techniques such as radiotelemetry and radio-active tagging.
4. Examine effects of different forms of resource management (e.g., different silvicultural treatments, varied fire regimes, habitat restoration) on populations of both species.

## LITERATURE CITED

- Anderson, J. D., and G. K. Williamson. 1976. Terrestrial mode of reproduction in Ambystoma cingulatum. *Herpetologica* 32:214-221.
- Ashton, R. E., Jr. 1992. Flatwoods Salamander. Pp 39-43 *In*: P. E. Moler, ed. Rare and Endangered Biota of Florida, Vol. 3, Amphibians and Reptiles, second ed. Univ. Press of Florida, Gainesville.
- Bailey, M. A. 1990. Movement of the dusky gopher frog (Rana areolata sevosa) at a temporary pond in the lower coastal plain of Alabama. Pp 27-43 *In*: C.K. Dodd, Jr., R. E. Ashton, Jr., R. Franz, and E. Wester, eds. Proc. Eighth Ann. Mtg. Gopher Tortoise Council, Florida Mus. Nat. Hist., Gainesville.
- Bailey, M. A. 1991. The dusky gopher frog in Alabama. *J. Alabama Acad. Sci.* 62:28-34.
- Bauldauf, R. J. 1952. Climatic factors influencing the breeding migration of the spotted salamander, Ambystoma maculatum (Shaw). *Copeia* 1952:178-181.
- Beneski, J. T., Jr., E. J. Zalisko, and J. H. Larsen, Jr. 1986. Demography and migratory patterns of the eastern long-toed salamander, Ambystoma macrodactylum columbianum. *Copeia* 1986:398-408.
- Burt, W. H., and R. P. Grossenheider. 1976. A Field Guide to the Mammals, third ed. Houghton Mifflin Co., Boston, Massachusetts.
- Caldwell, J. P. 1986. Selection of egg deposition sites: a seasonal shift in the southern leopard frog, Rana sphenoccephala. *Copeia* 1986:249-253.
- Conant, R., and J. T. Collins. 1991. A Field Guide to Reptiles and Amphibians of Eastern and Central North America, third ed. Houghton Mifflin Co., Boston, Massachusetts.
- Davis, M. S., and G. W. Folkerts. 1986. Life history of the wood frog, Rana sylvatica LeConte (Amphibia: Ranidae), in Alabama. *Brimleyana* 12:29-50.
- Diemer, J. E. 1989. Gopherus polyphemus, Gopher Tortoise. Pp 14-16 *In*: I. R. Swingland and W. W. Klemens, eds. The Conservation Biology of Tortoises. Occ. Pap. IUCN/SSC, No. 5.
- Donnelly, M. A., C. Guyer, J. E. Juterbock, and R. A. Alford. 1994. Techniques for Marking Amphibians. Pp. 277-284 *In*: W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster, eds. Measuring and Monitoring Biological Diversity, Standard Methods for Amphibians. Smithsonian Institution Press, Washington.
- Douglas, M. E. 1979. Migration and sexual selection in Ambystoma jeffersonianum. *Canad. J. Zool.* 57:2303-2310.



- Einem, G. E., and L. D. Ober. 1956. The seasonal behavior of certain Florida Salientia. *Herpetologica* 12:205-212.
- Franz, R. 1986. The Florida gopher frog and Florida pine snake as burrow associates of the gopher tortoise in northern Florida. Pp 16-20 In: D. R. Jackson and R. J. Bryant, eds. The gopher tortoise and its community. Proc. Fifth Ann. Mtg. Gopher Tortoise Council, Florida State Museum, Gainesville.
- Franz, R., C. K. Dodd, Jr., and C. Jones. 1988. Life History Notes: Rana areolata aesopus (Florida gopher frog). Movement. SSAR Herpetological Review 19:33.
- Gentry, J. B., and M. H. Smith. 1968. Food habits and burrow associates of Peromyscus polionotus. *J. Mammalogy* 49:562-565.
- Godley, J. S. 1992. Gopher frog. Pp 15-19 In: P. E. Moler, ed., Rare and Endangered Biota of Florida, Vol. 3, Amphibians and Reptiles, second ed. Univ. Press of Florida, Gainesville.
- Husting, E. L. 1965. Survival and breeding structure in a population of Ambystoma maculatum. *Copeia* 1965:352-361.
- Jensen, J. B. 1994. Geographic Distribution. Rana capito sevosa (Dusky Gopher Frog). SSAR Herpetological Review 25:161.
- Jensen, J. B., J. G. Palis, and M. A. Bailey. 1995. Natural History Notes: Rana capito sevosa (Dusky Gopher Frog). Submerged Vocalization. SSAR Herpetological Review 26:98.
- Krenz, J. D., and D. E. Scott. 1994. Terrestrial courtship affects mating locations in Ambystoma opacum. *Herpetologica* 50:46-50.
- LaClaire, L. V., and R. Franz. 1991. Importance of isolated wetlands in upland landscapes. Pp 9-15. Proc. 2nd Ann. Mtg. Florida Lake Management Society.
- Lee, D. S. 1968. Herpetofauna associated with central Florida mammals. *Herpetologica* 24:83-84.
- Means, D. B. 1972. Notes on Autumn Breeding Biology of Ambystoma cingulatum (Cope) (Amphibia: Urodela: Ambystomatidae). *Assoc. Southeastern Biol. Bull.* 19:84.
- Means, D. B., J. G. Palis, and M. Baggett. In press. Effects of slash pine silviculture on a Florida population of the flatwoods salamander (Ambystoma cingulatum). *Conservation Biology*.
- Mount, R. H. 1975. The Reptiles and Amphibians of Alabama. Auburn University Agriculture Experimental Station, Auburn, Alabama.

- Palis, J. G. 1995. Geographic Distribution. Ambystoma cingulatum (Flatwoods Salamander). SSAR Herpetological Review 26:103.
- Palis, J. G. In press. Larval growth, development and metamorphosis of Ambystoma cingulatum on the Gulf Coastal Plain of Florida. Florida Scientist.
- Pechmann, J. H. K., and H. M. Wilbur. 1994. Putting declining amphibian populations in perspective: natural fluctuations and human impacts. Herpetologica 50:65-84.
- Peckham, R. S., and C. F. Dineen. 1955. Spring migration of salamanders. Indiana Acad. Sci. 64:278-280.
- Phillips, C. A., and O. J. Sexton. 1989. Orientation and sexual differences during breeding migrations of the spotted salamander, Ambystoma maculatum. Copeia 1989:17-22.
- Raymond, L. R., and L. M. Hardy. 1990. Demography of a population of Ambystoma talpoideum (Caudata: Ambystomatidae) in Northwestern Louisiana. Herpetologica 46:371-382.
- Robbins, L. E., and R. L. Myers. 1992. Seasonal Effects of Prescribed Burning in Florida: a Review. Tall Timber Research Station, Inc., Misc. Publ. No. 8.
- Scott, D. E. 1994. The effect of larval density on adult demographic traits in Ambystoma opacum. Ecology 75:1383-1396.
- Semlitsch, R. D. 1981. Terrestrial activity and summer home range of the mole salamander (Ambystoma talpoideum). Can. J. Zool. 59:315-322.
- Semlitsch, R. D. 1983. Structure and dynamics of two breeding populations of the eastern tiger salamander, Ambystoma tigrinum. Copeia 1983:608-616.
- Semlitsch, R. D. 1985a. Analysis of climatic factors influencing migrations of the salamander, Ambystoma talpoideum. Copeia 1985:477-489.
- Semlitsch, R. D. 1985b. Reproductive strategy of a facultatively paedomorphic salamander Ambystoma talpoideum. Oecologia 65:305-313.
- Shoop, C. R., and T. L. Doty. 1972. Migratory orientation by marbled salamanders (Ambystoma opacum) near a breeding area. Behav. Biol. 7:131-136.
- Spotila, J. R. 1972. Role of temperature and water in the ecology of lungless salamanders. Ecological Monographs 42:95-125.
- Stenhouse, S. L. 1985. Migratory orientation and homing in Ambystoma maculatum and Ambystoma opacum. Copeia 1985:631-637.

United States Department of Agriculture. 1980. Soil Survey of Santa Rosa County, Florida.  
USDA Soil Cons. Serv.

United States Department of Agriculture. 1989. Soil Survey of Walton County, Florida.  
USDA Soil Cons. Serv.

United States Department of Agriculture. In prep. Soil Survey of Okaloosa County, Florida  
- preliminary soils maps. USDA Soil Cons. Serv.

Wood, D. A. 1992. Official lists of endangered and potentially endangered fauna and flora  
in Florida. Florida Game and Fresh Water Fish Comm., Tallahassee.

Wright, A. H. 1931. Life Histories of the Frogs of the Okefinokee Swamp, Georgia.  
MacMillan Co., New York.

Wright, A. H., and A. A. Wright. 1933. Handbook of Frogs and Toads of the United States  
and Canada. Comstock Publ. Assoc., Ithaca, New York.

Table 1: Vertebrates captured or observed at the Holley Pond drift fence from 14 October 1994 through 19 May 1995.

### AMPHIBIANS

<u>Acris gryllus</u>	southern cricket frog
<u>Bufo quercicus</u>	oak toad
<u>Bufo terrestris</u>	southern toad
<u>Gastrophryne carolinensis</u>	eastern narrowmouth toad
<u>Hyla femoralis</u>	pine woods treefrog
<u>Notophthalmus viridescens</u>	central newt
<u>Plethodon grobmani</u>	southeastern slimy salamander
<u>Pseudacris ornata</u>	ornate chorus frog
<u>Rana capito</u>	gopher frog
<u>Rana sphenoccephala</u>	southern leopard frog
<u>Scaphiopus holbrookii</u>	eastern spadefoot toad

### REPTILES

<u>Agkistrodon piscivorus</u>	cottonmouth
<u>Anolis carolinensis</u>	green anole
<u>Apalone ferox</u>	Florida softshell turtle
<u>Cnemidophorus sexlineatus</u>	six-lined racerunner
<u>Coluber constrictor</u>	racer
<u>Deirochelys reticularia</u>	chicken turtle
<u>Eumeces fasciatus</u>	five-lined skink
<u>Eumeces laticeps</u>	broadhead skink
<u>Heterodon platirhinos</u>	eastern hognose snake
<u>Kinosternon subrubrum</u>	eastern mud turtle
<u>Micrurus fulvius</u>	eastern coral snake
<u>Nerodia fasciata</u>	banded water snake
<u>Sceloporus undulatus</u>	fence lizard
<u>Scincella lateralis</u>	ground skink
<u>Sistrurus miliarius</u>	pygmy rattlesnake
<u>Tantilla coronata</u>	crowned snake
<u>Terrapene carolina</u>	box turtle

### MAMMALS

<u>Cryptotis parva</u>	least shrew
<u>Geomys pinetis</u>	southeastern pocket gopher
<u>Neotoma floridana</u>	eastern woodrat
<u>Ochrotomys nuttalli</u>	golden mouse
<u>Peromyscus gossypinus</u>	cotton mouse
<u>Peromyscus polionotus</u>	oldfield mouse
<u>Sigmodon hispidus</u>	hispid cotton rat
<u>Sus scrofa</u>	feral hog
<u>Sylvilagus floridanus</u>	eastern cottontail

Table 2: Vertebrates captured or observed at the EG-40 drift fence from 9 October 1993 through 31 March 1994, and 27 October 1994 through 19 May 1995.

## AMPHIBIANS

<u>Acris gryllus</u>	southern cricket frog
<u>Ambystoma cingulatum</u>	flatwoods salamander
<u>Amphiuma means</u>	two-toed amphiuma
<u>Bufo quercicus</u>	oak toad
<u>Bufo terrestris</u>	southern toad
<u>Eleutherodactylus planirostris</u>	greenhouse frog
<u>Eurycea quadridigitata</u>	dwarf salamander
<u>Gastrophryne carolinensis</u>	eastern narrowmouth toad
<u>Hyla femoralis</u>	pine woods treefrog
<u>Notophthalmus viridescens</u>	central newt
<u>Plethodon grobmani</u>	southeastern slimy salamander
<u>Pseudacris nigrita</u>	southern chorus frog
<u>Pseudacris ornata</u>	ornate chorus frog
<u>Rana clamitans</u>	bronze frog
<u>Rana sphenoccephala</u>	southern leopard frog

## REPTILES

<u>Anolis carolinensis</u>	green anole
<u>Cnemidophorus sexlineatus</u>	six-lined racerunner
<u>Coluber constrictor</u>	racer
<u>Deirochelys reticularia</u>	chicken turtle
<u>Diadophis punctatus</u>	ringneck snake
<u>Elaphe guttata</u>	corn snake
<u>Eumeces anthracinus</u>	coal skink
<u>Farancia abacura</u>	mud snake
<u>Heterodon platirhinos</u>	eastern hognose snake
<u>Kinosternon subrubrum</u>	eastern mud turtle
<u>Lampropeltis getula</u>	eastern kingsnake
<u>Nerodia fasciata</u>	banded water snake
<u>Opheodrys aestivus</u>	rough green snake
<u>Ophisaurus attenuatus</u>	slender glass lizard
<u>Ophisaurus ventralis</u>	eastern glass lizard
<u>Regina rigida</u>	glossy crayfish snake
<u>Sceloporus undulatus</u>	fence lizard
<u>Scincella lateralis</u>	ground skink
<u>Sistrurus miliarius</u>	pygmy rattlesnake
<u>Storeria occipitomaculata</u>	redbelly snake
<u>Tantilla coronata</u>	crowned snake
<u>Terrapene carolina</u>	box turtle
<u>Thamnophis sauritus</u>	eastern ribbon snake
<u>Thamnophis sirtalis</u>	eastern garter snake

Table 2 continued

BIRDS

Dendroica pinus  
Mimus polyglottos  
Troglodytes aedon

pine warbler  
mockingbird  
house wren

MAMMALS

Sigmodon hispidus

hispid cotton rat

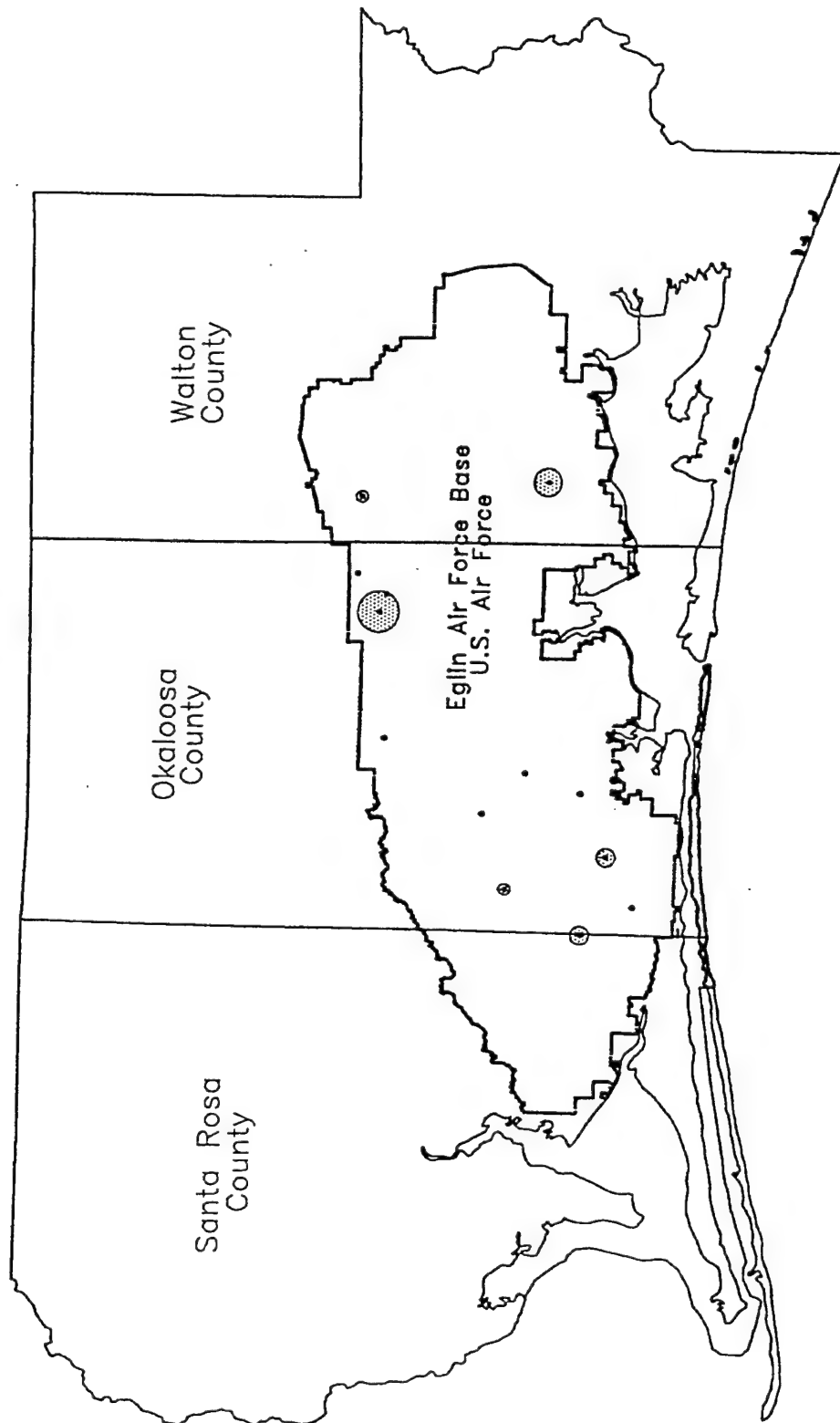
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\* A possibility exists that one or more specimens may have represented O. mimicus, the mimic glass lizard.



Figure 1: Map of occurrences of gopher frogs on Eglin AFB, Florida.

# Distribution of Gopher Frog (Rana capito) on Eglin Air Force Base



Scale



## Legend

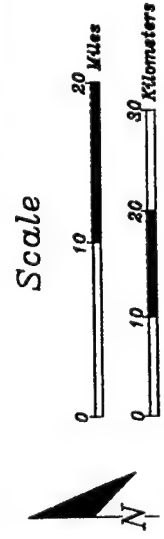
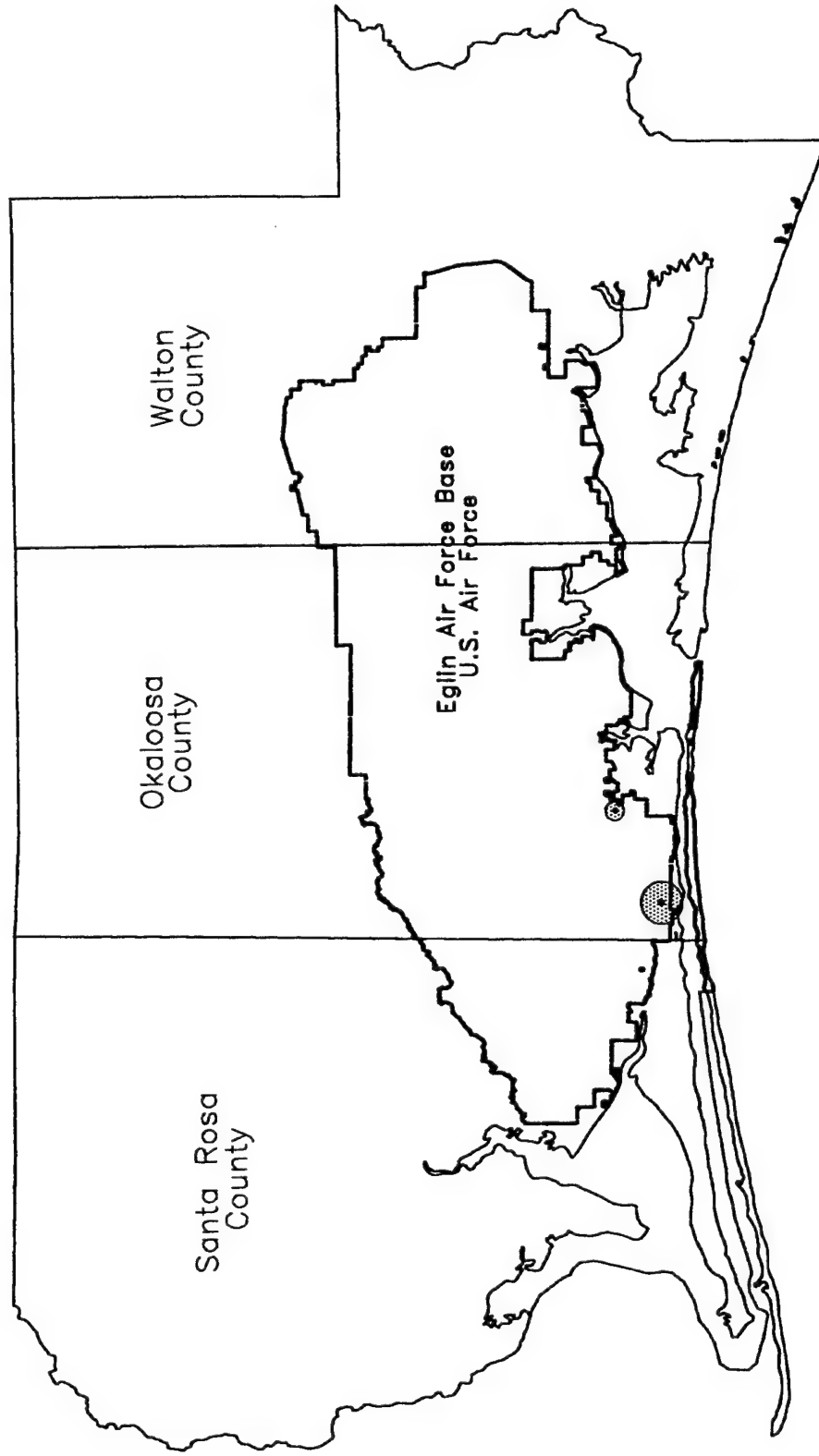
- = Gopher Frog occurrence
- N = Eglin Air Force Base boundary

Number of Ponds  
Per Element Occurrence



Figure 2: Map of occurrences of flatwoods salamanders on Eglin AFB, Florida.

# Distribution of Flatwoods Salamander (*Ambystoma cingulatum*) on Eglin Air Force Base



**Legend**

• = Flatwoods Salamander occurrence  
 N = Eglin Air Force Base boundary

**Number of Ponds  
Per Element Occurrence**

• 1  
 ● 3  
 ● 21

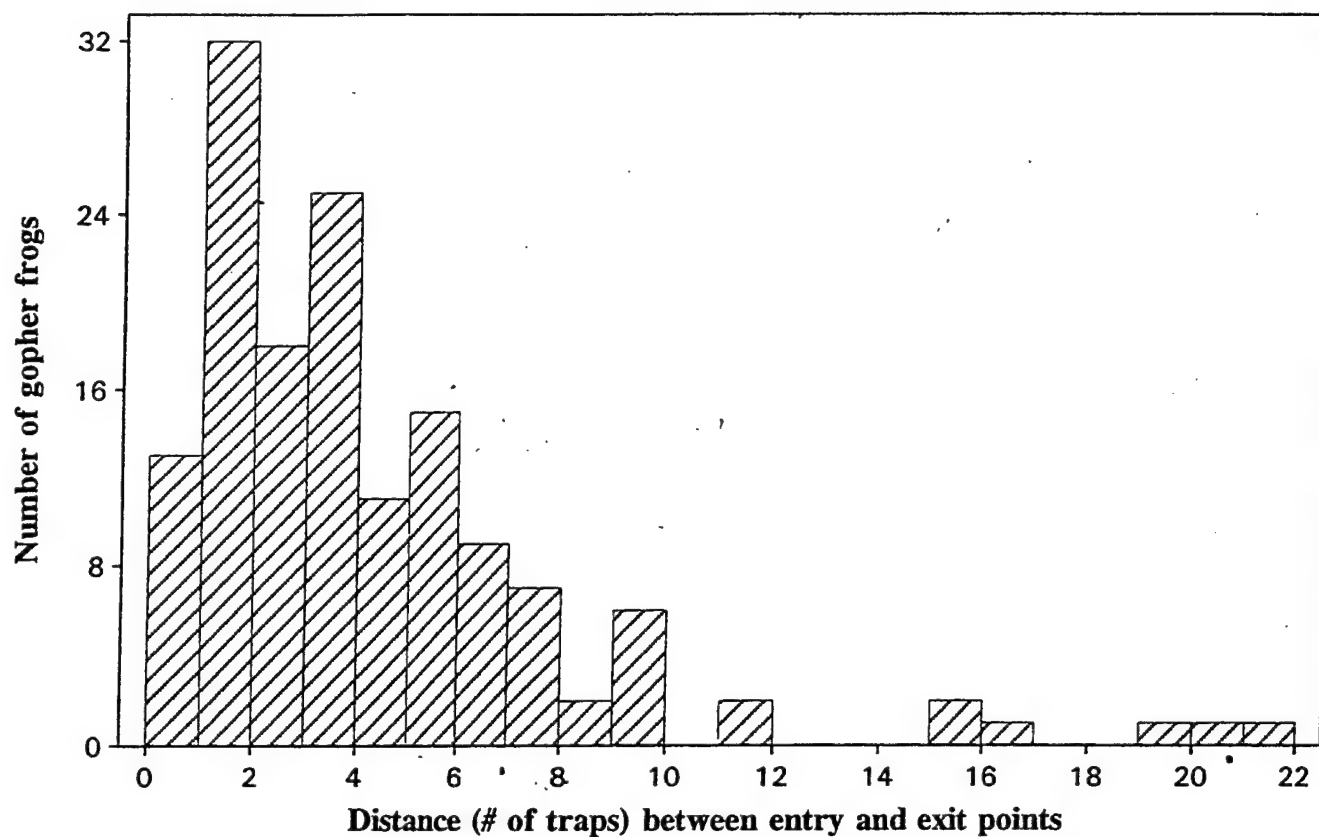


Figure 4: Size-frequency distribution of 136 adult female gopher frogs captured at Holley Pond (snout-vent length in mm).

[illegible]

Figure 5: Distance between entry and exit points for 146 gopher frogs at Holley Pond.





Number of Salamanders

SVL   01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

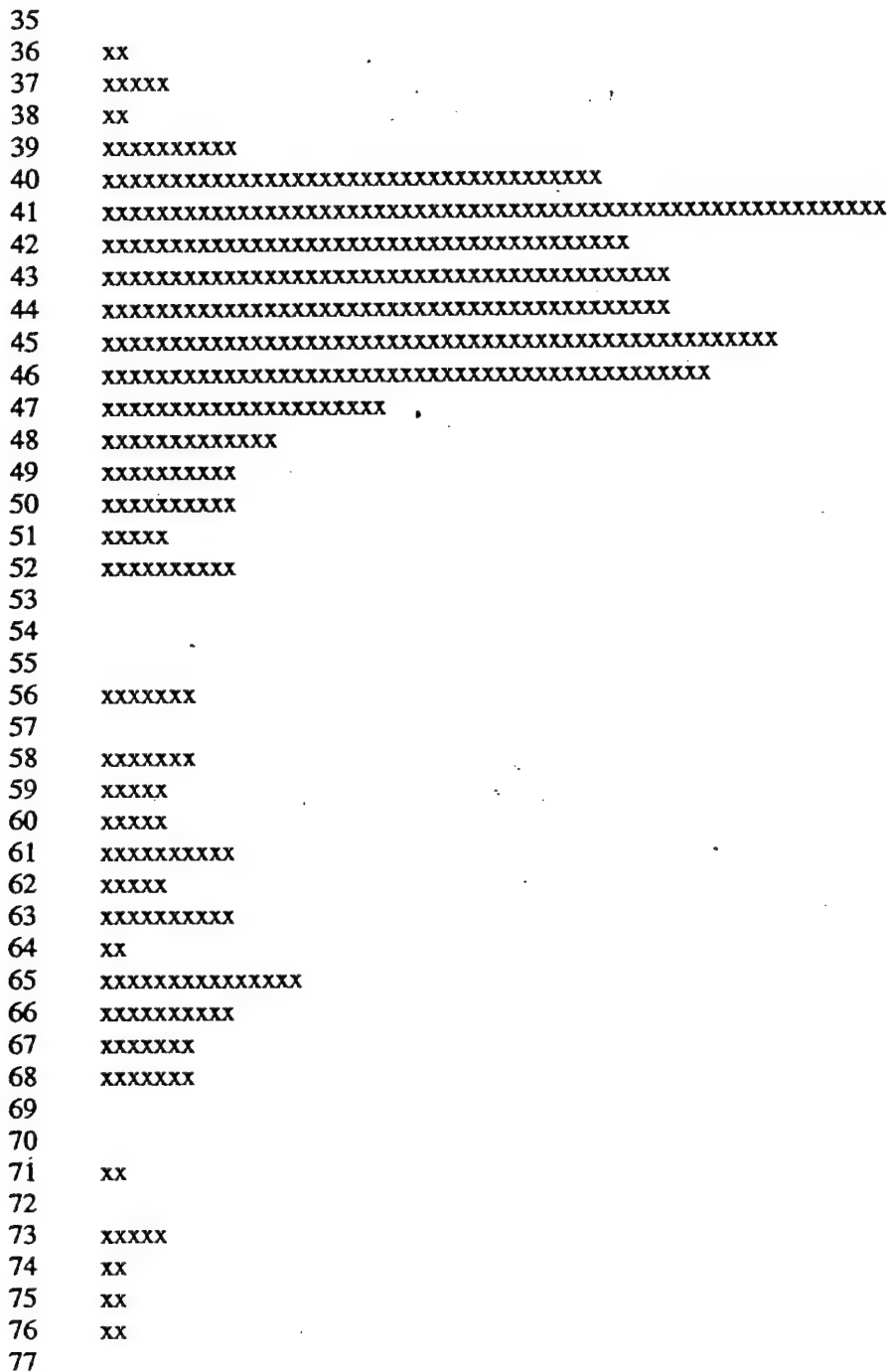
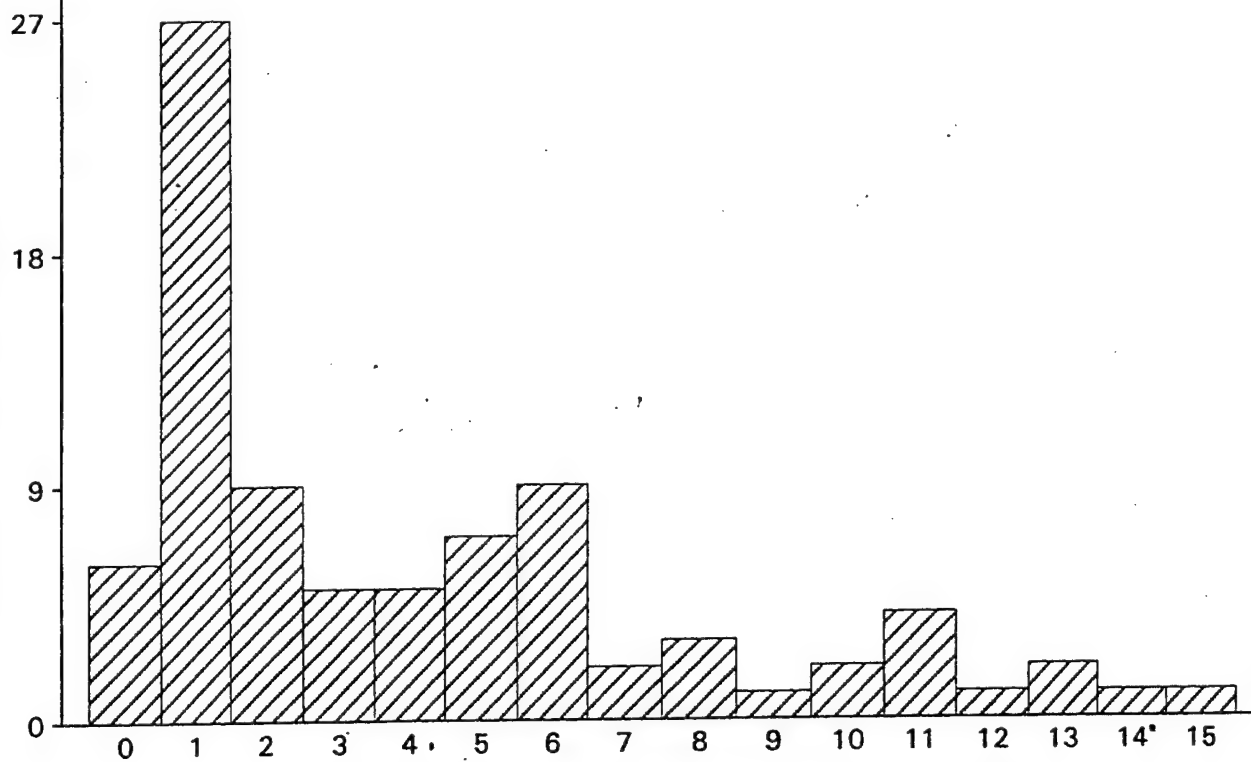
SVL   01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

Figure 7: Distance between entry and exit points of 85 flatwoods salamanders at breeding site EG-40, 1993 - 1994.

Number of flatwoods salamanders



Distance (# of traps) between entry and exit points

Appendix I: Location of potential gopher frog breeding sites on Eglin Air Force Base, Florida (arranged by EG number, then alphanumerically for sites not given EG numbers). Location includes county; USGS 7.5 minute topographic map; and township, range, section, and subsection coordinates.

- 1) EG 04 Okaloosa: Holt SW: T1N, R25W, Sec 28 (NE 1/4).  
Examined 20 Jan 1993.
- 2) EG 06 Okaloosa: Mary Esther: T1S, R25W, Sec 23 (SE 1/4).  
Examined 20 Jan 1993, 10 Nov 1993, 28 Jan 1994, 3 Feb 1994, 20 Feb 1994, 24 Feb 1994, and 8 Mar 1994. Two hatching Rana egg masses were observed on 10 Nov 1993, but could not be positively identified to species. Supports a small population of yellow bullheads.
- 3) EG 13 Okaloosa: Holt SW: T1N, R24W, Sec 6 (SE 1/4, border of Sec 7).  
Examined 21 Jan 1993, 15 Feb 1994 and 7 Mar 1994. Supports a relatively closed canopy of blackgum - shows poor potential as a gopher frog reproductive site.
- 4) EG 17 Okaloosa: Crestview South: T2N, R23W, Sec 9 (SW 1/4 of SW 1/4).  
Examined 29 Jan 1993, 13 Feb 1993, 2 Feb 1994 and 15 Feb 1994 (dry).
- 5) EG 18 Okaloosa: Crestview South: T2N, R23W, Sec 18 (NW 1/4 of NW 1/4).  
Examined 29 Jan 1993, 6 and 13 Feb 1993, and 15 Feb 1994 (dry).
- 6) EG 20 Okaloosa: Crestview South: T2N, R24W, Sec 13 (extreme NE corner).  
Examined 29 Jan 1993, 6 Feb 1993, 15 Feb 1994 (dry), and 5 Oct 1994.
- 7) EG 21 Okaloosa: Crestview South: T2N, R23W, Sec 29 (SE 1/4 of SW 1/4).  
Examined 30 Jan 1993, 14 Feb 1994 (dry) and 24 Feb 1994 (dry).
- 8) EG 22 Okaloosa: Holt SW: T1N, R24W, Sec 17 (NE 1/4 of SW 1/4).  
Examined 30 Jan 1993, 15 Feb 1994, 7 Mar 1994, and 6 Oct 1994. Supports dense growth of evergreen shrubs and trees on perimeter.

Appendix I, continued

- 9) EG 23 Okaloosa: Holt SW: T1N, R24W, Sec 34 (NW 1/4 of NE 1/4).  
Examined 30 Jan 1993, 12 Feb 1993, 4 Feb 1994 and 1 Mar 1994. Utilized by spadefoot toads for reproduction. May be too ephemeral to serve as a gopher frog breeding site.
- 10) EG 24 Okaloosa: Spencer Flats: T2N, R22W, Sec 8 (W edge of NE 1/4).  
Examined 31 Jan 1993, 2 Feb 1994 (dry), 7 Mar 1994 (dry), and 5 Oct 1994.
- 11) EG 25 Okaloosa: Spencer Flats: T2N, R22W, Sec 8 (NE 1/4 of SW 1/4 of NE 1/4).  
Examined 31 Jan 1993, 2 Feb 1994 (dry), 7 Mar 1994 (dry), and 5 Oct 1994.
- 12) EG 32 Okaloosa: Niceville: T1N, R22W, Sec 26 (NE 1/4 of NW 1/4).  
Examined 9 Feb 1993 and 20 Feb 1994 (dry).
- 13) EG 33 Okaloosa: Niceville: T1N, R22W, Sec 13 (NE 1/4 of NE 1/4).  
Examined 9 Feb 1993 and 20 Feb 1994 (dry).
- 14) EG 34 Okaloosa: Niceville: T1N, R22W, Sec 29 (NE 1/4 of NW 1/4).  
Examined 9 Feb 1993.
- 15) EG 36 Walton: Mossy Head: T2N, R21W, Sec 3 (SW 1/4 of SW 1/4).  
Examined 10 Feb 1993 and 14 Feb 1994 (dry).
- 16) EG 38 Walton: Mossy Head: T2N, R21W, Sec 10 (NE 1/4).  
Examined 10 Feb 1993 and 14 Feb 1994 (dry).
- 17) EG 39 Okaloosa: Niceville: T1N, R22W, Sec 24 (SW 1/4).  
Examined in 1993 and on 20 Feb 1994 (dry).
- 18) EG 82 Okaloosa: Crestview South: T2N, R23W, Sec 8 (SW 1/4 of SW 1/4).  
Examined in 1993 and on 15 Feb 1994, 7 Mar 1994, and 5 Oct 1994. Heavily wooded - shows poor potential as a gopher frog reproductive site.
- 19) EG 83 Walton: Niceville SE: T1S, R21W, Sec 3 (SW 1/4 of SE 1/4).  
Examined in 1993 (nearly dry), and on 20 Feb 1994 (dry) and 10 May 1994. Shows potential as a gopher frog reproductive site.

Appendix I, continued

- 45) J2 Walton: Niceville SE: T1N, R21W, Sec 4 (N 1/2).  
Examined in 1993 and deemed unsuitable for gopher frog reproduction by Kelly Irwin.
- 46) K2 Okaloosa: Holt: T2N, R25W, Sec 25 (SW 1/4 of NW 1/4).  
Examined in 1993 and deemed unsuitable for gopher frog reproduction by Kelly Irwin.
- 47) L2 Okaloosa: Holt: T2N, R24W, Sec 30 (NW 1/4 of SW 1/4).  
Examined in 1993 and deemed unsuitable for gopher frog reproduction by Kelly Irwin.
- 48) M2 Okaloosa: Holt: T2N, R24W, Sec 30 (SW 1/4 of SW 1/4).  
Examined in 1993 and deemed unsuitable for gopher frog reproduction by Kelly Irwin.
- 49) N2 Okaloosa: Holt: T2N, R24W, Sec 31 (W edge of NW 1/4 of NW 1/4).  
Examined in 1993 and deemed unsuitable for gopher frog reproduction by Kelly Irwin.
- 50) R2 Okaloosa: Mary Esther: T1S, R24W, Sec 16 (just S of center).  
Examined 5 Feb 1993 (dry).
- 51) Bull Pond Walton: Mossy Head: T2N, R21W, NW 1/4 of Sec 17 and SW corner of Sec 8.  
Examined 28 Feb 1994. Deemed unsuitable for gopher frog reproduction due to the presence of a large centrarchid population.
- 52) XXXX Walton: Mossy Head: T2N, R21W, Sec 9 (S 1/2 near border of Sec 16).  
Examined 28 Feb 1994. Permanent beaver pond at head of seepage inhabited by centrarchids, rendering it unsuitable for gopher frog reproduction.



Appendix II: Location of potential flatwoods salamander breeding sites on Eglin Air Force Base, Florida (arranged by EG number). Location includes county; site name; USGS 7.5 minute topographic map; and township, range, section, and subsection.

- 1) EG 01 Santa Rosa: Whitmier Island Savanna: Harold SE: T1N, R26W, Sec 17 (extreme NE 1/4).  
No larvae encountered on 18 Jan 1993 (323 meter-long dipnet sweeps), 21 Feb 1993 (300 dipnet sweeps), 23 Mar 1993 (150 dipnet sweeps), or 24 Mar 1994 (216 dipnet sweeps). No adults intercepted at 15.25-m long drift fence between 20 Oct and 21 Dec 1993. Wetland and surrounding terrestrial habitat appears suitable for flatwoods salamanders.
- 2) EG 14 Walton: Basin Bayou Pine Plantation: Freeport: T1S, R20W, Sec 22 (SW 1/4 of NW 1/4).  
No larvae encountered on 22 Jan 1993 (300 dipnet sweeps). Pond has a sparse graminaceous groundcover beneath a closed canopy. The surrounding savanna has been drastically altered by ditching and by the establishment of a closed-canopy slash pine plantation. Shows poor potential as a flatwoods salamander breeding site.
- 3) EG 15 Walton: Basin Bayou Pine Plantation: Freeport: T1S, R20W, Sec 22 (SW 1/4 of NW 1/4).  
No larvae encountered on 22 Jan 1993 (230 dipnet sweeps). Pond has a sparse graminaceous groundcover beneath a closed canopy. The surrounding savanna has been drastically altered by ditching and by the establishment of a closed-canopy slash pine plantation. Shows poor potential as a flatwoods salamander breeding site.
- 4) EG 16 Walton: Basin Bayou Pine Plantation: Freeport: T1S, R20W, Sec 23 (N 1/2 of NW 1/4).  
No larvae encountered on 22 Jan 1993 (75 dipnet sweeps). Pond has almost no graminaceous groundcover beneath the closed canopy. The surrounding savanna has been drastically altered by ditching and by the establishment of a closed-canopy slash pine plantation. Shows poor potential as a flatwoods salamander breeding site.
- 5) EG 31 Okaloosa: Turtle Creek Flatwoods: Mary Esther: T1S, R24W, Sec 20 (SE 1/4).  
No larvae encountered on 5 Feb 1993 (210 dipnet sweeps). Limited graminaceous vegetation in pond. Shows poor potential as a flatwoods salamander breeding site.

Appendix II, continued

- 6) EG 41 Santa Rosa: Panther Creek Savanna: Navarre: T2S, R26W, Sec 12 (SE 1/4 of NW 1/4).  
No larvae encountered when sampled on 16 Feb 1993 (dipnet sweeps not counted). No well defined wetland present, just scattered, shallow pools in dense graminaceous vegetation. Shows poor potential as a flatwoods salamander breeding site.
- 7) EG 42 Okaloosa: Heliport Savanna: Navarre: T2S, R25W, Sec 7 (SW 1/4 of SW 1/4).  
No larvae encountered on 16 Feb 1993 (210 dipnet sweeps). Site shows moderate potential as a flatwoods salamander breeding site.
- 8) EG 49 Santa Rosa: Hicks Creek Savanna: Ward Basin: T1N, R27W, Sec 33 (top center of S 1/2).  
No larvae encountered on 20 Feb 1993 (20 dipnet sweeps). Water was confined to small, shallow pools. Shows poor potential as a flatwoods salamander breeding site.
- 9) EG 50 Santa Rosa: Moore Creek Savanna: Ward Basin: T1N, R27W, Sec 24 (E 1/2 of SE 1/4, on border of Sec 19).  
No larvae encountered on 20 Feb 1993 (270 dipnet sweeps) or 9 Mar 1993 (200 dipnet sweeps). Site shows moderate flatwoods salamander potential.
- 10) EG 53 Okaloosa: Fort Walton Beach Savanna: Mary Esther: T1S, R24W, Sec 31 (SE 1/4).  
No larvae encountered on 23 Feb 1993 (too shallow to sweep), 25 Jan 1994 (dipnet sweeps uncounted) or 5 Apr 1994 (dipnet sweeps uncounted). Water confined to small, isolated shallow, sphagnaceous pools. Shows poor potential as a flatwoods salamander breeding site.
- 11) EG 54 Okaloosa: Fort Walton Beach Savanna: Mary Esther: T1S, R24W, Sec 31 (SE 1/4).  
No larvae encountered on 23 Feb 1993 (10 dipnet sweeps) or 5 Apr 1994 (88 dipnet sweeps). Water is principally confined to small, shallow, sphagnaceous pools. Shows poor potential as a flatwoods salamander breeding site.
- 12) EG 55 Santa Rosa: Moore Creek Savanna: Ward Basin: T1N, R27W, Sec 24 (N 1/2 of SE 1/4).  
No larvae encountered on 2 Mar 1993 (215 dipnet sweeps). Site shows moderate potential as a flatwoods salamander breeding site.

Appendix II, continued

- 13) EG 56 Santa Rosa: Moore Creek Savanna: Ward Basin: T1N, R27W, Sec 24 (S 1/2 of SE 1/4).  
No larvae encountered on 2 Mar 1993 (50 dipnet sweeps). No well defined wetland; site consists of a low, wet, savanna.
- 14) EG 57 Okaloosa: Fort Walton Beach Savanna: Mary Esther: T1S, R24W, Sec 29 (SW 1/4 of SW 1/4).  
Sampled 23 Mar 1994: no larvae encountered in 88 meter-long dipnet sweeps. Water is confined to shallow, isolated, densely-vegetated pools. Shows poor potential as a flatwoods salamander breeding site.
- 15) EG 58 Okaloosa: Fort Walton Beach Savanna: Mary Esther: T1S, R24W, Sec 31 (NE corner of SW 1/4 of NE 1/4).  
No larvae encountered on 29 Mar 1994 (33 dipnet sweeps). Water confined to shallow, isolated pools. Entire basin is ecotonal in character. Shows poor potential as a flatwoods salamander breeding site.
- 16) EG 59 Okaloosa: East Bay Flatwoods: Mary Esther: T2S, R25W, Sec 15 (NE 1/4 of NW 1/4).  
No larvae encountered on 6 Mar 1993 (60 dipnet sweeps). Pond has a dense midstory which has restricted growth of graminaceous groundcover vegetation. Shows poor potential as a flatwoods salamander breeding site.
- 17) EG 63 Santa Rosa: Whitmier Island Savanna: Harold SE: T1N, R26W, Sec 17 (center of section).  
No larvae encountered on 9 Mar 1993 (35 dipnet sweeps). Little water in which to sweep. Shows poor potential as a flatwoods salamander breeding site.
- 18) EG 64 Walton: Linton Spring Branch - Trout Creek Flatwoods: Choctaw Beach: T1S, R20W, Sec 20 (NW 1/4 of NW 1/4).  
No larvae encountered on 10 Mar 1993 (25 dipnet sweeps). Shallow pond is choked with algae. Shows poor potential as a flatwoods salamander breeding site.
- 19) EG 67 Okaloosa: East Bay Flatwoods: Navarre: T2S, R25W, Sec 7 (Center of S 1/2 of SW 1/4).  
No larvae encountered on 15 Mar 1993 (50 dipnet sweeps). Ditched, shallow wetland dominated by Lycopodium. Shows poor potential as a flatwoods salamander breeding site.

Appendix II, continued

- 20) EG 74 Okaloosa: East Bay Flatwoods: Mary Esther: T2S, R25W, Sec 15 (SE 1/4 of NE 1/4 of NE 1/4).  
No larvae encountered on 2 Apr 1993 (75 dipnet sweeps). Ditched, shallow wetland shows poor potential as a flatwoods salamander breeding site.
- 21) EG 76 Okaloosa: East Bay Flatwoods: Mary Esther: T2S, R25W, Sec 11 (W 1/2 of SW 1/4 of SW 1/4).  
No larvae encountered on 2 Apr 1993 (10 dipnet sweeps). Very little graminaceous vegetation present. Shows poor potential as a flatwoods salamander breeding site.
- 22) EG 77 Okaloosa: East Bay Flatwoods: Mary Esther: T2S, R25W, Sec 14 (N 1/2 of NW 1/4).  
No larvae encountered on 2 Apr 1993 (25 dipnet sweeps). Very little graminaceous vegetation present. Shows poor potential as a flatwoods salamander breeding site.
- 23) EG 78 Okaloosa: East Bay Flatwoods: Mary Esther: T2S, R25W, Sec 15 (NW 1/4 of NE 1/4).  
No larvae encountered on 6 Apr 1993 (35 dipnet sweeps). Very little graminaceous vegetation present (dominated by Sphagnum sp.). Shows poor potential as a flatwoods salamander breeding site.
- 24) EG 79 Okaloosa: East Bay Flatwoods: Navarre: T2S, R25W, Sec 17 (E 1/2 of NE 1/4).  
No larvae encountered on 17 Mar 1994 (209 dipnet sweeps).  
Sphagnum sp. dominates wetland basin; however, site shows potential as a flatwoods salamander breeding site.
- 25) EG 81 Santa Rosa: East Bay Flatwoods: Navarre: T2S, R26W, Sec 13 (near center of NE 1/4).  
No larvae encountered on 26 Jan 1994 (dipnet sweeps not counted) or 23 Feb 1994 (72 dipnet sweeps). Site shows little potential as a flatwoods salamander breeding site under 1994 hydrologic conditions.
- 26) EG 91 Okaloosa: Navarre: East Bay Flatwoods: T2S, R25W, Sec 17 (NW 1/4 of NE 1/4 of NE 1/4).  
No larvae encountered on 17 Mar 1994 (67 dipnet sweeps). Habitat appears suitable for flatwoods salamander reproduction; however, ecotone not inundated.

Appendix II, continued

- 27) EG 92 Okaloosa: Mary Esther: T1S, R25W, Sec 34 (NW 1/4 of SW 1/4 of SE 1/4).  
No larvae encountered on 23 Mar 1994 (31 dipnet sweeps). Habitat appears suitable for flatwoods salamander reproduction; however, wetland is not located within extensive flatwoods or savanna habitat which is thought to be needed by post-metamorphic flatwoods salamanders.
- 28) EG 93 Okaloosa: Navarre: East Bay Flatwoods: T2S, R25W, Sec 17 (center of NE 1/4 of SE 1/4).  
No larvae encountered on 25 Mar 1994 (214 dipnet sweeps). Habitat appears suitable for flatwoods salamander reproduction; however, wetland lies within transition zone between relatively xeric flatwoods and coastal scrub -- habitat which may be too dry for post-metamorphic flatwoods salamanders.
- 29) Okaloosa: Holt: Malone Creek Flatwoods: T2N, R25W, Secs 13, 14, 18, 19, and 24.  
Area not examined during survey.
- 30) Okaloosa: Crestview South: Shoal River Flatwoods: T2N, R23W, Sec 7 (NW 1/4).  
Area not examined during survey.
- 31) Santa Rosa: Holley: Long Branch Savanna: T1S, R27W, Secs 31, 36, and 30/37 juncture.  
Area not examined during survey.
- 32) Santa Rosa: Ward Basin: Boiling Creek Savanna: T1N, R26W, Secs 19 and 20.  
Area not examined during survey.

Appendix III: Survey dates and observations of gopher frog breeding activity at reproductive sites surveyed from 1993 - 1995 on Eglin Air Force Base, Florida (arranged by EG number). Location includes County; USGS 7.5 minute topographic map; township, range, section, and subsection coordinates; and directions.

- 1) EG 03 Okaloosa: Harold SE: T1N, R25W, Sec 28 (NE corner). Holley Pond: Approx. 50 yards W of RR 213, at junction of RR 675 (or 1.4 mi S of RR 257).
  - 20 Jan 1993: 62 egg masses
  - 21 Jan 1993: two or three males heard calling
  - 09 Nov 1993: 46 egg masses
  - 29 Jan 1994: 12 adults captured and released
  - 31 Jan 1994: males heard calling
  - 01 Feb 1994: five egg masses and six adults observed
  - 06 Feb 1994: 20 adults observed
  - 09 Feb 1994: 61 egg masses
  - 01 Mar 1994: three adults observed
  - 01 Oct 1994 - 19 May 1995: 320 frogs captured at drift fence; 156 egg masses
- 2) EG 05 Okaloosa: Holt SW: T1N, R25W, Sec 28 (NE 1/4 of NE 1/4). Approx. 0.1 mi W of woods road, 0.2 mi N of RR 675, 0.25 mi E of RR 213.
  - 20 Jan 1993: 10 egg masses
  - 09 Nov 1993: 14 egg masses
  - 01 Mar 1994: four adults observed
- 3) EG 07 Okaloosa: Mary Esther: T1S, R25W, Sec 26 (extreme NE corner). NW corner of large depression at SW corner of junction of RR 253 and RR 682 (1.9 mi S of RR 678).
  - 20 Jan 1993: one egg mass
  - 28 Jan 1994: nearly dry, no egg masses or frogs
- 4) EG 08 Okaloosa: Mary Esther: T1S, R25W, Sec 26 (NE 1/4 of NE 1/4). 0.2 mi SW of junction of RR 253 and RR 682 (1.9 mi S of RR 678).
  - 20 Jan 1993: nine egg masses
  - 05 Mar 1994: two egg masses
- 5) EG-09 Okaloosa: Mary Esther: T1S, R25W, Sec 26 (N 1/2 center of section). West side of woods road, 0.15 mi S of RR 682, 0.425 mi W of RR 253.
  - 20 Jan 1993: no egg masses or frogs
  - 10 Nov 1993: site dry
  - 03 Oct 1994: one egg mass

Appendix IV: Survey dates and observations of flatwoods salamander breeding activity at reproductive sites surveyed from 1993 - 1994 on Eglin Air Force Base, Florida (arranged by EG number). Location includes County; USGS 7.5 minute topographic map; township, range, section, and subsection coordinates; and directions.

- 1) EG 02 Okaloosa: Navarre: T2S, R25W, Sec 17 (S 1/2 of NW 1/4). Approx. 20 yards S of power line road, 0.6 mi W of RR 259 (0.5 mi N of hwy 98).  
18 Jan 1993: one larva collected in 430 dipnet sweeps  
30 Mar 1994: one larva captured in 33 dipnet sweeps
- 2) EG 40 Okaloosa: Navarre: T2S, R25W, Sec 17 (NW 1/4 of SE 1/4 of NE 1/4). Approx. 25 yards W of woods road, 50 yards N of power line road, 0.075 mi E of RR 259 (0.5 mi N of hwy 98).  
14 Feb 1993: one larva collected in 30 dipnet sweeps  
15 Apr 1994: two larvae captured in 35 dipnet sweeps  
30 Nov 1994: no larvae captured (dipnet sweeps uncounted)  
04 Jan 1995: no larvae captured (dipnet sweeps uncounted)  
19 Feb 1995: no larvae captured (dipnet sweeps uncounted)  
02 Apr 1995: no larvae captured (dipnet sweeps uncounted)  
13 Apr 1995: no larvae captured (dipnet sweeps uncounted)  
15 Apr 1995: no larvae captured (dipnet sweeps uncounted)  
17 Apr 1995 - 19 May 1995: no larvae captured (three single-opening funnel traps)
- 3) EG 43 Okaloosa: Mary Esther: T2S, R25W, Sec 10 (S 1/2 of SW 1/4). Approx. 50 yards W of RR 253, 0.1 mi N of RR 668.  
17 Feb 1993: one larva collected in seven dipnet sweeps  
01 Mar 1994: one larva captured in 35 dipnet sweeps
- 4) EG 44 Okaloosa: Navarre: T2S, R25W, Sec 9 (SE 1/4 of SE 1/4). Approx. 75 yards N of RR 668, 0.6 mi NW of RR 253.  
17 Feb 1993: one larva collected in six dipnet sweeps  
24 Jan 1994: five larvae captured (dipnet sweeps uncounted)
- 5) EG 45 Okaloosa: Navarre: T2S, R25W, Sec 9 (S 1/2 of SE 1/4). Approx. 75 yards SW of RR 668, 0.6 mi NW of RR 253.  
17 Feb 1993: one larva collected in two dipnet sweeps  
20 Jan 1994: no larvae observed (low water)  
11 Apr 1994: no larvae observed in 71 dipnet sweeps (low water)



Appendix IV, continued

- 6) EG 46 Okaloosa: Navarre: T2S, R25W, Sec 9 (SW 1/4 of SE 1/4 of SW 1/4).  
Approx. 100 yards SE of woods road, about 0.2 mi S of RR 668, 0.45 mi  
E of RR 259.  
17 Feb 1993: one larva collected in three dipnet sweeps  
24 Jan 1994: 20 larvae captured (dipnet sweeps uncounted)  
19 Feb 1995: no larvae captured (dipnet sweeps uncounted)  
24 Apr 1995: no larvae captured (dipnet sweeps uncounted)
- 7) EG 47 Okaloosa: Navarre: T2S, R25W, Sec 16 (N 1/2). Approx. 100 yards S of  
woods road, about 0.2 mi S of RR 668, 0.45 mi E of RR 259.  
17 Feb 1993: one larva collected in 30 dipnet sweeps  
05 Apr 1994: one larva captured in 118 dipnet sweeps
- 8) EG 48 Okaloosa: Navarre: T2S, R25W, Sec 8 (S edge of SW 1/4 of SE 1/4).  
Approx. 25 yards W of RR 259, 0.1 mi S of RR 668.  
17 Feb 1993: one larva collected in 81 dipnet sweeps  
01 Mar 1994: one larva captured in 23 dipnet sweeps
- 9) EG 51 Okaloosa: Mary Esther: T1S, R24W, Sec 32 (NE 1/4 of NE 1/4). Approx.  
25 yards S of RR 636, ca. 0.1 mi W of RR 655.  
22 Feb 1994: one larva collected in three dipnet sweeps
- 10) EG 52 Approx. 100 yards S of RR 636, ca. 0.1 mi W of RR 655.  
Mary Esther: T1S, R24W, Sec 32 (NE 1/4 of NE 1/4).  
22 Feb 1994: one larva collected in four dipnet sweeps
- 11) EG 60 Okaloosa: Mary Esther: T2S, R25W, Sec 10 (SW 1/4 of SW 1/4). Approx.  
25 yards N of RR 668, 0.425 mi NW of RR 253.  
06 Mar 1993: one larva collected in five sweeps  
25 Mar 1994: no larvae observed in 131 dipnet sweeps  
28 Apr 1994: no metamorphs observed
- 12) EG 61 Okaloosa: Navarre: T2S, R25W, Sec 17 (W 1/2 of NE 1/4). Approx. 10  
yards N of power line road, 0.15 mi W of RR 259 (0.5 mi N of hwy 98).  
06 Mar 1993: one larva collected in six dipnet sweeps  
01 Mar 1994: one larva captured in 117 dipnet sweeps
- 13) EG 62 Okaloosa: Navarre: T2S, R25W, Sec 17 (center of N 1/2 of NW 1/4).  
Approx. 20 yards N of power line road, 0.5 mi W of RR 259 (0.5 mi N of  
hwy 98).  
11 Mar 1993: one larva collected in 45 dipnet sweeps  
30 Mar 1994: one larva captured in 86 dipnet sweeps

## DISTRIBUTION, HABITAT, AND STATUS OF THE FLATWOODS SALAMANDER (*AMBYSTOMA CINGULATUM*) IN FLORIDA, USA

John G. Palis<sup>1</sup>

Florida Natural Areas Inventory,  
1018 Thomasville Road, Suite 200-C, Tallahassee, Florida 32303, USA

**Abstract.** I surveyed 393 wetlands in 22 Florida counties for the presence of *Ambystoma cingulatum* larvae from 1990–1995. I sampled wetlands at or near previous collection sites, or sites elsewhere that were ecologically similar. In addition, I sampled 24 breeding sites annually from 1991–1995 to assess variation in reproductive success. Larval *A. cingulatum* were observed at 82 sites (20.8%) in 11 counties. Breeding sites were small ( $\bar{x}$  = 1.49 ha), shallow ( $\bar{x}$  = 39.2 cm), acidic ( $\bar{x}_{\text{pH}}$  = 4.2), isolated wetlands in pine flatwoods or savanna. Sixty-five of these known breeding sites (79.3%) occurred on public lands. Three times as many wetlands were sampled on public than private lands, but breeding sites were encountered with similar frequency on public (22.2%) and private (17%) lands. Thirty-one (70.5%) of 44 historic collection sites were resampled; larvae were observed at 11 (35.5%) of these. Proportionally, more extant breeding sites occurred in pine flatwoods or savanna (42.3%) than in pine plantations (11.4%). There are at least 33 breeding populations of *A. cingulatum* in Florida, 24 of which (73%) are known from only one breeding site. *Ambystoma cingulatum* larvae were observed in 6–23 (12–96%) of the 24 breeding sites sampled annually. Sampling success was presumed to reflect breeding success, which, in turn, was thought to be influenced by variation in seasonal patterns and amount of rainfall. Threats to the species may include habitat conversion for silviculture, agriculture, and real estate development; fertilizer application; road construction; and bait harvesting. The species' apparent susceptibility to anthropogenic alterations of the landscape suggests that its status in Florida is precarious and that legal protection is warranted.

**Key Words.** Flatwoods salamander; *Ambystoma cingulatum*; Distribution; Status; Florida

The flatwoods salamander, *Ambystoma cingulatum*, inhabits mesic longleaf pine (*Pinus palustris*) flatwoods and savannas from southern South Carolina, southward along the Atlantic Coastal Plain to north-central Florida, and west through the Gulf Coastal Plain to southern Alabama (Conant and Collins 1991). *Ambystoma cingulatum* migrates to breeding sites from October–December during and immediately following rains associated with cold fronts (Anderson and Williamson 1976; Palis 1997).

Eggs are deposited terrestrially and hatch upon inundation (Anderson and Williamson 1976). The larvae may attain a total length of 96 mm and transform in 11–18 weeks (Palis 1995). *Ambystoma cingulatum* is considered endangered in South Carolina (Palis 1996) and rare in Alabama (Means 1986), Georgia (Palis 1996), and Florida (Ashton 1992). In 1995, the U. S. Fish and Wildlife Service (USFWS) eliminated the category in which *A. cingulatum* was listed (C2; USFWS 1996).

*Ambystoma cingulatum* is believed to have undergone a rangewide population decline as a result of habitat conversion for silviculture, agriculture, and

<sup>1</sup> Present address: 529 N. Main Street, Jonesboro, Illinois 62952, USA

residential and commercial development (Bury et al. 1980; Means 1986; Means et al. 1996). Consensus opinion of southeastern herpetologists convened by the USFWS in January 1991 (Tallahassee, Florida) indicated that federal listing of *A. cingulatum* as threatened may be appropriate. At that meeting, state synopses indicated that few recent sightings existed and little was known regarding the species' endangerment status. This survey was initiated to determine the present distribution and status of the species in Florida.

### HISTORICAL BACKGROUND

Prior to this survey, *Ambystoma cingulatum* was known in Florida from 44 historic localities in 14 counties (Fig. 1, Table 1). Florida specimens of *A. cingulatum* have been collected sporadically since at least 1853 (Goin 1950). *Ambystoma cingulatum* is generally not observed unless a concerted effort is made to locate it. Goin (1950) noted that little new information had accumulated following the original description of *A. cingulatum* due to the difficulty in securing specimens. Although rarely observed, historic collections indicate that *A. cingulatum* was once locally common. For example, Goin (1950) described the collection of 45 *A. cingulatum* by four University of Florida students in two hours of searching a cutover pine flatwoods in Jackson County in April 1950. In the early 1950s, *A. cingulatum* was regularly collected at a site near Gainesville, Alachua County (Mecham and Helman 1952; R. Highton, pers. comm. 1993; S. Telford, pers. comm. 1993), and in the early 1970s, large numbers of *A. cingulatum* could be observed crossing roads during fall breeding migrations at sites in Calhoun and Liberty counties (B. Means, pers. comm. 1990).

### MATERIALS AND METHODS

Because post-metamorphic *Ambystoma cingulatum* are secretive and difficult to collect reliably without specialized techniques such as drift-fencing, I determined presence by sampling known or potential breeding sites for the aquatic larvae. Depending on accessibility and sampling success, I sampled each

site from 1–5 times during a 1–3 yr period. In some instances, historic collection data were too imprecise to permit relocation of original collecting sites. Where collection data failed to specify road miles or straight-line air miles, as well as starting points of the distances measured, I attempted to locate potential breeding ponds on a map in the general vicinity of the straight-line distance indicated by the collector. In the field, I drove the specified distance from a designated city, using major intersections and current city limits as alternate starting points. Historic records are curated by the Florida Natural Areas Inventory, Tallahassee, Florida, and with the exception of one literature-based record (Neill 1954), are supported by specimens in museums or private collections.

I selected potential *Ambystoma cingulatum* breeding sites from U.S. Soil Conservation Service county soil surveys, Florida Department of Transportation aerial photographs, U.S. Geological Survey topographic maps, and field reconnaissance. Special effort was made to identify ponds near historic collections of adult salamanders. Identification of changes in soil type and topography, especially from xeric uplands to mesic pine flatlands below the 30.5 m contour often led to the discovery of previously unreported sites. Private property was entered only if not posted or with owner permission.

At each site I dipnetted during the day using a 4 mm mesh nylon dipnet (Mid-Lakes Corporation, Knoxville, Tennessee; net no. SH-2) that was 41 cm wide. To standardize the effort made at each site, each meter-long dipnet sweep was tallied as one sweep. The net was forced through submerged vegetation, within which larval *Ambystoma cingulatum* take refuge during daylight hours (Palis 1995, 1996). Most larvae were taken as follows: First, the bag of the net was submerged in the water adjacent to the vegetation to be sampled. The vegetation was then swept by foot or hand toward the net, and the net then thrust through the vegetation in the opposite direction. In deeper, less densely vegetated areas, I swept the net back and forth vigorously through inundated vegetation in an overlapping zig-zag pattern. Occasionally, I made multiple parallel sweeps in the same direction in near-shore shallow water. I also conducted limited nocturnal dipnet and flashlight surveys, overnight minnow-trap sampling (Gee 6 mm wire mesh funnel

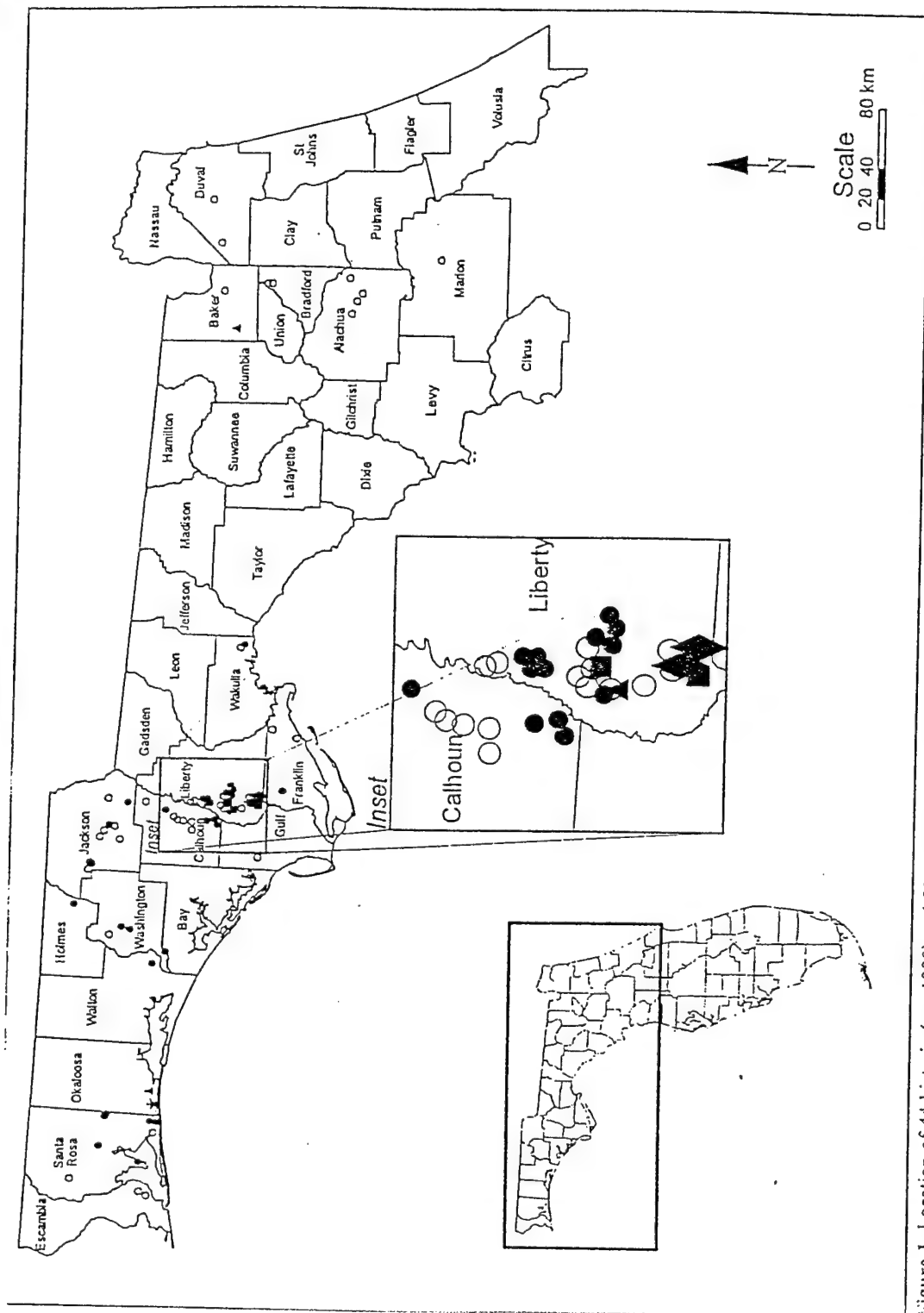


Figure 1. Location of 44 historic (pre-1990) and 82 recent (1990-1995) *Ambystoma cingulatum* collections. Open symbols indicate historic collections, closed symbols indicate recent collections. Each circle indicates one collection site. Multiple breeding sites are indicated by a square ( $n = 2$ ), a triangle ( $n = 3$ ), a diamond ( $n = 10$ ), or a star ( $n = 21$ ).

trap), and seine sampling. Dipnet surveys were principally conducted between mid-February and mid-March 1990–1995, although some surveys were initiated in mid-January or continued through early April. A single voucher specimen was collected from each site.

In 1993 and 1994 I recorded the following environmental variables at most sites: pH (determined with a Hanna pocket pH meter calibrated at a temperature near ambient), water temperature (measured with a pocket thermometer), and maximum water depth (measured with a meter stick). I recorded overstory, midstory, and ground cover (i.e., bottom) vegetation, as well as vegetation of the terrestrial habitat immediately surrounding the site. I estimated percent canopy and groundcover coverage and noted visually dominant species. I scored the terrestrial habitat surrounding 347 sites according to level of anthropogenic disturbance as follows: 1 = second-growth longleaf and/or slash pine (*Pinus elliottii*) flatwoods or savanna with a nearly undisturbed wiregrass (*Aristida stricta*) dominated groundcover; 2 = a slash or sand pine (*P. clausa*) plantation with a relatively intact wiregrass groundcover; and 3 = a slash or sand pine plantation from which wiregrass has been nearly eliminated. Loss of wiregrass is indicative of site degradation from fire suppression and/or soil disturbance (Clewett 1989). In cases where more than one disturbance category applied, I recorded the most prevalent category.

For most sites sampled in 1993 I recorded the depth at which larvae were captured, the distance of the capture site from shore, and identified the vegetation from which larvae were extricated. Other amphibians, reptiles, fishes, and macroinvertebrates encountered were identified to the lowest readily identifiable taxonomic level.

To examine annual variation in reproductive success of *Ambystoma cingulatum*, 24 known breeding sites on the Apalachicola National Forest (ANF), Liberty County, were sampled with diurnal dipnetting annually from 1991–1995. The vegetated portions of each site were thoroughly sampled without pre-determined limits set on time or number of dipnet sweeps. The presence or absence of larvae presumably indicated reproductive success or failure.

## RESULTS

### Present Distribution

*Ambystoma cingulatum* larvae were collected at 82 of 393 (20.8%) Florida sites sampled and in 11 of 22 (50%) counties surveyed from 1990–1995 (Fig. 1, Table 1). Larvae were observed at 65 of 293 (22.2%) sites sampled on public lands and 17 of 100 (17%) sites surveyed on private lands. A total of 79.3% of known breeding sites occur on public lands, 98.5% ( $n = 64$ ) of which are in federal ownership. Seventy-one (86.6%) sites represent new locations for the species, including three new counties (Holmes, Okaloosa, Walton). Larvae were captured at two of 13 (15.4%) historic breeding sites, and in wetlands near nine of 18 (50%) historic non-breeding sites. Overall, *A. cingulatum* was reconfirmed at 11 of 31 (35.5%) historic sites. Thirteen historic sites were not resampled because locality data were too vague, access was denied, or potential breeding sites were not located.

The elevation of recent and historic breeding sites that were located ( $n = 106$ ) averaged 16.5 m above sea level (1.5–64 m). Ninety-one sites (85.8%) are below 30.5 m, the level of the Wicomico shoreline, the earliest and highest of the Pleistocene seas that inundated portions of Florida during interglacial periods (Webb 1990).

### Larval Observations

During a typical sampling effort, the first larva was encountered after an average of 39 (1–220,  $n = 59$ ) meter-long dipnet sweeps in an average of 11 (1–52,  $n = 57$ ) min. Each sweep was 0.4 m wide; thus 2.5 meter-long sweeps sampled roughly 1 m<sup>2</sup> of surface area. Therefore, an average of 39 sweeps represents an average of one larva per 16 m<sup>2</sup> of habitat sampled or a density of 0.06 larvae per m<sup>2</sup>. Because I sampled microhabitats preferred by *Ambystoma cingulatum* larvae, the density of larvae throughout the entire breeding site was probably lower. Larvae were taken from inundated herbaceous vegetation within an average of 4.1 m from shore (0.25–21.0 m,  $n = 48$ ) and at a mean depth of 16.65 cm (8.0–34.0 cm,  $n = 66$ ). Sixty-eight percent of larvae ( $n = 111$ ) were encountered in panic grass (*Panicum erectifolium*—14%, *P. rigidulum*—6%), three-awned grass (*Aristida*

*affinis*—13%), pipewort (*Eriocaulon compressum*—11.5%), beakrush (*Rhynchospora corniculata*—10.5%), bluestem (*Andropogon* sp.—7.5%), and clubmoss (*Lycopodium* spp.—6%). The remaining 52 larvae (32%) were captured less frequently (0.6–4.3%) among 18 other cover types, including 15 other plant species, and grass and/or pine needle litter. In two ponds sampled with minnow traps, one larva was captured in 93 trap-hours at one site, and no larvae were captured in 60 trap-hours at another pond where larval presence was confirmed by dipnet.

Larvae were observed at 6–23 of the 24 (12–96%) known breeding sites sampled annually between 1991 and 1995. Larvae were observed in all five years at

three (12%) breeding sites, four years at seven (29%) breeding sites, three years at nine (38%) breeding sites, and from zero to two years at five (21%) breeding sites. On average, larvae were encountered in each pond in three of five years. During the five-year period, the first larva of each sampling was captured in an average of 9.5 min (1–52 min,  $n = 66$ ) and 33 dipnet sweeps (1–153 sweeps,  $n = 45$ ). The average of 33 sweeps represents a mean of one larva per 13 m<sup>2</sup> of habitat sampled or a density of 0.07 larvae per m<sup>2</sup>. The densities of *Ambystoma cingulatum* larvae observed in this study were similar to those observed by Sekerak (1994) in random sweeps (0.004–0.13 lar-

Table 1. Summary of historic (pre-1990) and recent (1990–1995) observations of *Ambystoma cingulatum* in Florida. Location of historic observations include breeding site (B), road (R), forest or unrecorded (F). The last two columns indicate the number of historic and new breeding sites where *A. cingulatum* was observed during this survey.

County	Historic Observations			Sites Sampled	Historic Breeding Sites	New Breeding Sites
	B	R	F			
Alachua	3	0	1	13	0	0
Baker	1	0	0	52	0	3
Bay	0	0	0	3	0	0
Bradford	2	0	0	4	0	0
Calhoun	4	0	2	29	1	3
Clay	0	0	0	4	0	0
Columbia	0	0	0	14	0	0
Duval	0	0	2	6	0	0
Escambia	1	0	1	2	0	0
Franklin	1	1	0	14	0	1
Gulf	0	0	1	2	0	0
Holmes	0	0	0	4	0	1
Jackson	2	1	4	11	2	1
Leon	0	0	0	4	0	0
Liberty	1	5	5	135	6	30
Marion	0	0	1	1	0	0
Okaloosa	0	0	0	40	0	24
Santa Rosa	2	0	1	28	1	4
Union	0	0	0	3	0	0
Wakulla	0	0	1	8	1	0
Walton	0	0	0	9	0	1
Washington	0	0	1	7	0	3
Totals	17	7	20	393	11	71

vae/m<sup>2</sup>), but much less than those observed for *Ambystoma opacum* by Petranks (1989) in random collections (3.3–20.1 larvae/m<sup>2</sup>).

In 1993, seven known *Ambystoma cingulatum* breeding sites required 2–3 visits to confirm presence of larvae. Five ponds, sampled unsuccessfully in February, yielded larvae in March; one pond, sampled unsuccessfully in January, yielded a larva in February; and one pond, sampled unsuccessfully in January and February, yielded a larva in March.

### Habitat

*Ambystoma cingulatum* breeding sites are isolated wetlands in pine flatwoods or savanna that typically dry completely for several weeks during the growing season. Breeding sites generally fill in late autumn or early winter (October–January) and begin to dry in April and May with the onset of the growing season—a period of intensified evapotranspiration and reduced rainfall. Breeding sites for which size estimates are available ( $n = 46$ ) ranged from 0.03–12.7 ha ( $\bar{x} = 1.49$  ha). Average maximum water depth (39.2 cm, 18–102 cm,  $n = 80$ ), water temperature (15.5°C, 8.5–26°C,  $n = 81$ ), and pH (4.2, 3.4–5.6,  $n = 78$ ) of *A. cingulatum* breeding sites did not differ significantly from the average maximum depth (37 cm, 13–100 cm,  $n = 87$ ), water temperature (15.2°C, 8.0–24°C,  $n = 76$ ) and pH (4.2, 3.6–6.1,  $n = 73$ ) of similar sites where *A. cingulatum* was not observed ( $t = 0.8$ ,  $df = 165$ ,  $P = 0.38$ ;  $t = 0.52$ ,  $df = 155$ ,  $P = 0.6$ ;  $t = -0.91$ ,  $df = 149$ ,  $P = 0.3$ , respectively). Limestone-based fill material may have accounted for relatively high pH (5.0–6.1) of roadside ponds. Water temperature varied with time of day, cloud cover, and season.

The overstory of breeding sites was dominated by pond cypress (*Taxodium ascendens*), blackgum (*Nyssa sylvatica* var. *biflora*), and slash pine (Table 2). Estimates of canopy coverage ranged from near zero to almost 100%. The midstory was dominated by myrtle-leaved holly (*Ilex myrtifolia*), but included a variety of shrubs and small trees (Table 2). In ponds dominated by narrow-leaved forms such as pond cypress and/or slash pine, a substantial amount of light penetrated the relatively open canopy. This often resulted in the development of a dense midstory. Depending upon overall closure of the canopy and midstory, a

dense or sparse groundcover was developed. In open situations, herbaceous vegetation covered virtually 100% of the pond floor. Where the broad-leaved blackgum dominated, the floor of the wetland was densely shaded during the growing season, restricting the establishment of a midstory and herbaceous groundcover. In some blackgum-dominated ponds, only ca. 5% of the pond floor was covered by herbaceous vegetation.

The groundcover of breeding sites was dominated by graminaceous species, but included a variety of forbs and mosses (Table 2). Filamentous algae, typically attached to other vegetation, also occurred sparsely in most *Ambystoma cingulatum* breeding ponds. The floor of breeding sites generally consisted of relatively firm mud with little or no peat. Breeding sites were completely or partially encircled by a graminaceous ecotone which gently graded into the wetland and surrounding uplands.

*Ambystoma cingulatum* breeding sites were inhabited by a variety of aquatic macroinvertebrates and vertebrates. Invertebrates collected with *A. cingulatum* larvae included freshwater sponges, leeches, burrowing crayfish (*Procambarus apalachicola*, *P. evermanni*, *P. hubbelli*, *P. kilbyi*, *P. leonensis*, *P. paeninsulanus*, *P. pubisclae*, *P. pycnogonopus*, *P. pygmaeus*, *Faxonella clypeata*), amphipods, isopods, fairy shrimp, fishing spiders (*Dolomedes* spp.), aquatic beetles (dytiscids, gyrids, hydrophilids), bugs (belostomatids, corixids, gerrids, hydrometrids, naucorids, nepids, notonectids), larvae of flies, nymphs of dobsonflies, dragonflies and damselflies, snails, and sphaerid clams. Because of their ephemeral nature, the ponds rarely contained more than a small suite of fishes, but harbored various other amphibians and reptiles (Table 3).

Fifty-eight (70.7%) breeding sites occurred within category-1 disturbance level second-growth pine flatwoods and savannas, 56 (96.5%) of which were on public lands; seven (8.5%) occurred within category-2 pine plantations; and 17 (20.7%) in category-3 pine plantations. Proportionally, more *Ambystoma cingulatum* breeding sites were surrounded by category-1 uplands (42.3%) than by category-2 uplands (9.8%) or category-3 uplands (12.2%;  $X^2 = 34.6$ ,  $df = 2$ ,  $P < 0.001$ ).



Table 2. Percent frequency of characteristic ( $\geq 25\%$  frequency per category) plants species of the overstory, midstory, and groundcover of 79 *Ambystoma cingulatum* breeding sites. Frequency values of some forms (e.g., forbs) should be considered a minimum because vegetation data were collected during dormancy when plants were inconspicuous.

Species	Overstory	Midstory	Groundcover
<i>Andropogon</i> sp.	-	-	73.4
<i>Aristida affinis</i>	-	-	93.6
<i>Carex</i> spp.	-	-	55.7
<i>Clethra alnifolia</i>	-	53.1	-
<i>Coreopsis nudata</i>	-	-	34.2
<i>Cyrilla racemiflora</i>	-	35.4	-
<i>Dichromena latifolia</i>	-	-	32.9
<i>Erianthus</i> spp.	-	-	40.5
<i>Eriocaulon compressum</i>	-	-	92.4
<i>E. decangulare</i>	-	-	46.8
<i>Helenium vernale</i>	-	-	27.8
<i>Hypericum brachyphyllum</i>	-	-	50.6
<i>H. chapmanii</i>	-	48.1	-
<i>H. fasciculatum</i>	-	30.4	-
<i>Ilex myrtifolia</i>	-	95.0	-
<i>Lobelia</i> spp.	-	-	55.7
<i>Lophiola americana</i>	-	-	49.4
<i>Lyonia lucida</i>	-	30.4	-
<i>Lycopodium</i> spp.	-	-	46.8
<i>Magnolia virginiana</i>	-	40.5	-
<i>Manisuris</i> spp.	-	-	29.1
<i>Nyssa sylvatica</i> var. <i>biflora</i>	64.5	-	-
<i>Oxypolis filiformis</i>	-	-	25.0
<i>Panicum erectifolium</i>	-	-	63.3
<i>P. rigidulum</i>	-	-	92.4
<i>Pieris phyllireifolius</i>	-	44.3	-
<i>Pinguicula planifolia</i>	-	-	40.5
<i>Pinus elliotii</i>	60.7	-	-
<i>Polygala cymosa</i>	-	-	48.0
<i>Rhexia</i> spp.	-	-	26.6
<i>Rhynchospora cephalantha</i>	-	-	49.4
<i>R. chalarocephala</i>	-	-	26.6
<i>R. corniculata</i>	-	-	78.5
<i>R. filifolia</i>	-	-	70.8
<i>Sabatia bartramii</i>	-	-	60.7
<i>Scleria baldwinii</i>	-	-	48.1
<i>Smilax laurifolia</i>	-	51.9	-
<i>Sphagnum</i> sp.	-	-	58.2
<i>Taxodium ascendens</i>	84.8	-	-
<i>Xyris</i> spp.	-	-	91.1

Table 3. Percent frequency of fishes, amphibians, and reptiles observed concurrently with *Ambystoma cingulatum* larvae at 81 *A. cingulatum* breeding sites. Frequency values should be viewed as a minimum because some species are more susceptible to dipnetting than others.

Fishes		Amphibians		Reptiles	
<i>Ameiurus natalis</i>	(3.7)	<i>Acris gryllus</i>	(59.2)	<i>Agkistrodon piscivorus</i>	(22.2)
<i>Centrarchus macropterus</i>	(1.2)	<i>Ambystoma talpoideum</i>	(6.2)	<i>Chelydra serpentina</i>	(2.5)
<i>Elassoma evergladei</i>	(54.3)	<i>Amphiuma means</i>	(1.2)	<i>Deirochelys reticularia</i>	(4.9)
<i>E. zonatum</i>	(1.2)	<i>Eurycea quadridigitata</i>	(77.7)	<i>Farancia abacura</i>	(1.2)
<i>Enneacanthus gloriosus</i>	(1.2)	<i>Notophthalmus viridescens</i>	(23.4)	<i>Kinosternon subrubrum</i>	(19.7)
<i>E. obesus</i>	(33.3)	<i>Pseudacris crucifer</i>	(1.2)	<i>Nerodia fasciata</i>	(4.9)
<i>Esox americanus</i>	(19.7)	<i>P. nigrita</i>	(51.8)	<i>Regina rigida</i>	(1.2)
<i>Etheostoma fusiforme</i>	(4.9)	<i>P. ocularis</i>	(20.9)	<i>Seminatrix pygaea</i>	(2.5)
<i>Fundulus auroguttatus</i>	(14.8)	<i>P. ornata</i>	(74.0)	<i>Terrapene carolina</i>	(8.6)
<i>F. escambiae</i>	(2.5)	<i>Pseudobranchius striatus</i>	(7.4)	<i>Thamnophis sauritus</i>	(2.5)
<i>F. lineolatus</i>	(1.2)	<i>Rana capito</i>	(1.2)		
<i>Gambusia holbrooki</i>	(43.2)	<i>R. clamitans</i>	(1.2)		
<i>Lepomis gulosus</i>	(1.2)	<i>R. grylio</i>	(20.9)		
<i>Leptolucania ommata</i>	(24.7)	<i>R. utricularia</i>	(79.0)		
		<i>Siren intermedia</i>	(4.9)		
		<i>S. lacertina</i>	(1.2)		

## DISCUSSION

### Distribution

*Ambystoma cingulatum* is presently known to breed in 82 ponds in Florida, 65 (79.3%) of which occur on public lands (Table 4). Most historic and recent Florida *A. cingulatum* occurrences (85.8%) lie below the Wicomico shoreline (30.5 m contour) in the Gulf Coastal Lowlands physiographic province (Puri and Vernon 1964). The habitat requirements of *A. cingulatum* may be best met in the pine communities that occur on the acidic, poorly drained, sandy spodosols which are prevalent below this shoreline (Fernald and Purdum 1992). The preponderance of *A. cingulatum* collections in this area may also be a result of land use history. Because of the relative infertility and seasonal saturation of the soils, this area was among the last in the longleaf pine belt to be exploited for agriculture. Thus, it contains some of the best remaining examples of longleaf pine flatwoods and savannas (Peet and Allard 1993).

Although within the Gulf Coastal Lowlands, the lower Suwannee River watershed (Dixie, Gilchrist, Lafayette, Levy, Madison, and Suwannee counties)

Table 4. Number of known, extant *Ambystoma cingulatum* breeding sites on public lands in Florida.

Tract of public land	Number of breeding sites
Apalachicola National Forest	35
Eglin Air Force Base	25
Osceola National Forest	3
Pine Log State Forest	1
St. Marks National Wildlife Refuge	1
Total	65

is devoid of *Ambystoma cingulatum* collections, as are the contiguous counties of Jefferson and Taylor to the west. Lack of *A. cingulatum* records from this 8-county area might be a result of sampling bias; however, similar disjunct ranges of other species, and lack of appropriate habitat suggest that the range gap is real.

Burgess and Franz (1978) listed nine species of gastropods, insects, fishes, and amphibians that have widely disjunct populations separated by the Suwannee River watershed. They speculated that in-

undation of the Suwannee River basin by rising sea water subsequent to the formation of the Wicomico shoreline resulted in the disjunct ranges of the species they examined. Although such a scenario could explain the disjunct range of *Ambystoma cingulatum*, its absence from this area is more likely due to the scarcity of habitat. Most of the area includes extensive, perennially-wet shrub-dominated wetlands, palm-hardwood hammocks, coastal marsh, and sandhill, none of which provide suitable habitat for *A. cingulatum*.

*Ambystoma cingulatum* also inhabits two widely separate portions of the Northern Highlands physiographic province: northeast Florida and the Marianna Lowlands (Holmes and Jackson counties). Harper (1914:330) described the northeast Florida flatwoods as "open forests of longleaf pine...bearing the marks of frequent fire," and (Harper 1914:203) the longleaf pine forests of Jackson County as "so open that wagons can be driven through them almost anywhere." He also noted (Harper 1914:330) that shallow forested ponds, "which dry up in spring, are frequent" in both areas. Both regions have been greatly altered for agriculture and silviculture, degrading or eliminating *A. cingulatum* habitat. Habitat conversion for agriculture in the Marianna Lowlands was already well under way at the turn of the century (Harper 1920). Due to the destruction and fragmentation of the longleaf pine ecosystem that continues today (Noss et al. 1995), and the paucity of historic *A. cingulatum* collections, it may not be possible to precisely delineate the historic range of *A. cingulatum* in Florida.

#### Annual Variation in Reproductive Success

Annual sampling of 24 known *Ambystoma cingulatum* breeding sites in the ANF from 1991–1995 suggests that *A. cingulatum* reproductive success varies among years because of variation in the seasonal pattern and amount of precipitation. Larvae were observed in 20–23 (83–96%) of the 24 ANF ponds in the winters of 1991, 1993, and 1994. These winters were preceded by years with total rainfall accumulations of 116.13–159.46 cm ( $\bar{x}$  = 135.83 cm), of which 31.06–39.12 cm ( $\bar{x}$  = 33.86 cm) fell between September and December (Tallahassee, Florida, airport).

Larvae were observed in only six of the 24 known breeding sites sampled during the 1992 and 1995 sample seasons. Although 1991 was a wet year (183.48 cm total rainfall accumulation), only 10.97 cm of rain fell from September–December, the bulk of which during daylight hours. This may have hindered the ability of adult *A. cingulatum* to migrate to breeding sites, since they typically migrate nocturnally during rain (Palis 1997). Other species of *Ambystoma* are known to skip breeding in years of low rainfall (Pechmann et al. 1991).

The fall of 1994 was extremely wet with 72.89 cm of rain falling between September and December. The bulk of this rain (57.0 cm) came in September and October, filling breeding sites beyond capacity. At an Eglin Air Force Base breeding site encircled with a drift fence, adult *Ambystoma cingulatum* were observed entering the flooded basin in October and November (Palis 1997). Spent females left the basin in November and December, presumably after ovipositing at the edge of the water. Subsequently, the water receded, and did not reach the same level again until the end of April 1995. Despite repeated dipnet and funnel trap surveys, larvae were not observed in 1995. Presumably all embryos perished by starvation or desiccation while encapsulated in their gelatinous envelopes. This scenario may have occurred at other flatwoods salamander breeding sites as well, resulting in a poor reproductive year for *A. cingulatum* throughout north Florida.

#### Survey Bias

The success of larval surveys relies, in part, upon successful reproduction. Because of the imprecision of dipnetting as a sampling method, I cannot be certain that negative results are due to poor breeding success or the true absence of an *Ambystoma cingulatum* population. In addition, I have demonstrated that breeding success varies annually depending upon amount and seasonal distribution of rainfall, so sites sampled only during poor reproductive years could miss *A. cingulatum* even if present (Pechmann et al. 1991). That only one larva was observed in six years of annually sampling one ANF pond suggests that some ponds may be used only occasionally for reproduction. That several known breeding sites had to be sampled more than once dur-

ing a single breeding season to document salamander reproduction suggests that sampling a site only once during a season may miss *A. cingulatum* even when present. Because of the limited time frame for this survey, the sources of sampling error described above, and the large number of new breeding sites found during this survey, it is clear that additional surveys of potential breeding sites are needed.

#### Conservation Status of, and Threats to, *Ambystoma cingulatum*

Radio-isotope tracking data show that *Ambystoma cingulatum* may move up to 1.6 km from a breeding site (Ashton 1992). Considering *A. cingulatum* movement data gathered by Ashton (1992) in conjunction with confirmed breeding pond distribution presented here, it appears that there are a minimum of 33 extant, breeding populations of *A. cingulatum* known in Florida (erroneously reported as 38 in Palis 1996). Breeding sites in close proximity (within 3.2 km) and not separated by natural barriers to movement (e.g., perennial streams), are considered to be part of the same metapopulation because animals breeding at disjunct ponds might be genetically linked by individuals that abandon their natal pond for others.

A potential threat to *Ambystoma cingulatum* is over-collection by the pet trade. Oftentimes, the rarer the species, the greater its commercial value. Fortunately, *A. cingulatum* is not presently collected commercially in Florida (Enge 1991). A threat to some breeding populations is the harvest of crayfish as bait. Bait harvesters drag large hardware-cloth buckets through inundated vegetation, dump the contents of the bucket on the ground, and then sort out the crayfish. *Ambystoma cingulatum* larvae taken in this manner are left to die or are collected for use as bait. Fertilization of pine plantations sometimes results in eutrophication of adjacent wetlands. This may exclude their use by *A. cingulatum*; I have never taken larvae from algae-choked wetlands or portions of wetlands choked with algae. The location of some *A. cingulatum* breeding ponds adjacent to roads leaves them vulnerable to road shoulder management, which sometimes includes the application of herbicides. Road construction also poses a threat to breeding sites. At least one presumed historic *A. cingulatum* breeding site in Escambia County has been filled for road

construction. Vehicular traffic may pose a threat to populations that live on one side of the road but breed on the other (Means et al. 1996).

Altered fire regimes and fire suppression also threaten some remaining *Ambystoma cingulatum* populations by habitat degradation. Lightning is believed to be the natural ignition source for fires that perpetuate the longleaf pine community and lightning-ignited fires occur most frequently between May and September (Robbins and Myers 1992). Natural landscape fires are now rare due to fire suppression or man-made fire breaks such as roads, agricultural fields, and developed areas. In the absence of fire, or under altered fire regimes (e.g., winter fire), woody plant species increase in dominance at the expense of grasses and forbs (Boyer 1993; Platt et al. 1988; Waldrop et al. 1992). The heliophilic groundcover community is lost through shading, and longleaf pine is replaced by fire-sensitive pines and shade-tolerant hardwoods (Means 1996; Means and Grow 1985; Ware et al. 1993).

Prescribed winter burning, a management tool replacing natural fire, has been widely used in Florida pinelands for vegetation control, but fire suppression is replacing prescribed fire due to smoke management and liability constraints (Wade 1993). Fire suppression is hastening the degradation of remaining *Ambystoma cingulatum* habitat. Fire suppression also degrades larval habitat by favoring fire-sensitive, broad-leaved hardwoods over pond cypress (Marois and Ewel 1983). The resultant shade eliminates herbaceous vegetation favored by *A. cingulatum* larvae.

Plantation forestry appears to be the greatest threat to *Ambystoma cingulatum* habitat in Florida, especially because of its prominence on poorly drained flatwoods and savanna soils. Florida is second among U.S. states in acreage of corporate tree farms, most of which occur in northern Florida (Fernald and Purdum 1992) in the range of *A. cingulatum*. Seventy-six percent of northwest Florida (Jefferson county westward) is classified as timberland, 74.3% of which is privately owned (Clark and Sheffield 1994). Pine stands compose 56% of these private timberlands, of which 74% are plantations (Clark and Sheffield 1994). Additional plantations include 27% of the pine stands on public lands in northwest Florida (Clark and Sheffield 1994). The area of pine planted in plantations is predicted to

increase as the remaining natural pine stands are harvested (Alig et al. 1990). Establishment of pine plantations on poorly drained sites, such as those inhabited by *A. cingulatum*, generally requires drainage by ditching and/or bedding (Harding and Hollis 1993). Ditching can drastically alter the hydrology of an area. Torbert et al. (1993) found that ditching lowered the water table as much as 1 m below the soil surface at a time when the water table was at the surface of unditched sites. Ditching can shorten wetland hydroperiods (Marois and Ewel 1983) and prevent successful *A. cingulatum* reproduction by preventing egg inundation or stranding larvae before they are capable of metamorphosis. Bedding, the practice of plowing the soil into long, parallel beds, creates both elevated, drier soils on the tops of the beds and wetter soils in the trenches between the beds (Schultz and Wilhite 1974). Means et al. (1996) suggested that changes in vegetation and soil microtopography and microclimate resulting from bedding likely contributed to a 98% decline of a north Florida *A. cingulatum* population. Although my survey suggests that at least some *A. cingulatum* can persist in or adjacent to pine plantations, it also demonstrates that *A. cingulatum* are more likely to occur in uplands supporting a relatively undisturbed, wiregrass-dominated groundcover than uplands having a disturbed, wiregrass-depauperate groundcover.

The presence of larvae provides no indication of the size or status of a breeding population. For example, larval presence in wetlands in the area where Means et al. (1996) conducted their study provided no corroborative evidence of the decline. Larval sampling conducted in this survey, however, did document the presumed extirpation of *A. cingulatum* at four historic sites surrounded by pine plantations.

Although *Ambystoma cingulatum* occurs on five tracts of public land in Florida, two of which appear to support relatively large and healthy populations, I believe the status of *A. cingulatum* in Florida is precarious. This conclusion is based upon the small number of known extant populations, the relatively large number of populations ( $n = 24$ ; 73%) known from only one breeding site, the species' apparent susceptibility to anthropogenic changes to the landscape (Means et al. 1996), the possible extirpation at 20 historic sites, and the magnitude of habitat alter-

ation in Florida. I recommend that legal protection be afforded *A. cingulatum* and I urge biologists to conduct additional surveys and studies of the species' natural history and response to habitat alteration.

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## LITERATURE CITED

- Alig, R.J., W.G. Hohenstein, B.C. Murray, and R.G. Haight. 1990. Change in area of timberlands in the United States, 1952-2040, by ownership, forest type, region and state. Gen. Tech. Rep. SE-64. USDA Forest Service, Southeastern Experiment Station, Asheville, North Carolina.
- Anderson, J.D. and G.K. Williamson. 1976. Terrestrial mode of reproduction in *Ambystoma cingulatum*. *Herpetologica* 32:214-221.
- Ashton, R.E., Jr. 1992. Flatwoods Salamander. In: P.E. Moler (ed.) *Rare and Endangered Biota of Florida, Vol. 3, Amphibians and Reptiles, 2nd Edition*, pp. 39-43. University Press of Florida, Gainesville, Florida.
- Boyer, W.D. 1993. Season of burn and hardwood development in young longleaf pine stands. In: J.C. Brissette (ed.) *Proceedings of the 7th Biennial Southern Silvicultural Research Conference*, pp. 511-515. Gen Tech. Rep. SO-93. USDA Forest Service, Southern Experiment Station, Auburn, Alabama.
- Burgess, G.H. and R. Franz. 1978. Zoogeography of the aquatic fauna of the St. Johns River system with comments on adjacent peninsular faunas. *Amer. Midl. Nat.* 100:160-170.
- Bury, R.B., C.K. Dodd, Jr., and G.M. Fellers. 1980. Conservation of the Amphibia of the United States: a review. *USFWS Biol. Rep.* 90:1-34.
- Clark, R.F., Jr. and R.M. Sheffield. 1994. Forest statistics for northwest Florida, 1994. Res. Bull. SE-148. USDA Forest Service, Southeastern Experiment Station, Asheville, North Carolina.
- Clewell, A.F. 1989. Natural history of wiregrass (*Aristida stricta* Michx., Gramineae). *Nat. Areas J.* 9:223-233.
- Conant, R. and J.T. Collins. 1991. *A Field Guide to Amphibians and Reptiles, Eastern and Central North America*. Houghton Mifflin Co., Boston, Massachusetts.
- Enge, K.M. 1991. Herptile exploitation. Annual Performance Report, Nongame Wildlife Section, Florida Game and Fresh Water Fish Commission, Tallahassee, Florida.
- Fernald, F.E. and E.D. Purdum. 1992. *Atlas of Florida*. University Press of Florida, Gainesville, Florida.
- Goin, C.J. 1950. A study of the salamander, *Ambystoma cingulatum*, with a description of a new subspecies. *Ann. Carnegie Mus.* 31:299-320.
- Harding, R.B. and C.A. Hollis. 1993. Growth response of slash pine to intensive drainage and bedding. In: J.C. Brissette (ed.) *Proceedings of the Seventh Biennial Southern Silvicultural Research Conference*, pp. 243-246. Gen. Tech. Rep. SO-93. USDA Forest Service, Southern Experiment Station, Auburn, Alabama.
- Harper, R.M. 1914. Geography and vegetation of northern Florida. Florida Geological Survey Sixth Annual Report, Tallahassee, Florida.
- Harper, R.M. 1920. Resources of southern Alabama. Geological Survey of Alabama, Special Rep. No. 11, Tuscaloosa, Alabama.
- Marois, K.C. and K.C. Ewel. 1983. Natural and management-related variation in cypress domes. *Forest Sci.* 29:627-640.
- Means, D.B. 1986. Special concern: flatwoods salamander. In: R.H. Mount (ed.) *Vertebrate Animals of Alabama in Need of Special Attention*, pp. 42-43. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama.
- Means, D.B. 1996. Longleaf Pine Forest, going, going, ... In: M. B. Davis (ed.) *Eastern Old-Growth Forests: Prospects for Rediscovery and Recovery*, pp. 210-229. Island Press, Washington, D.C.
- Means, D.B. and G. Grow. 1985. The endangered longleaf pine community. *Enfo*, September:1-12.
- Means, D.B., J.G. Palis, and M. Baggett. 1996. Effects of slash pine silviculture on a Florida panhandle population of flatwoods salamander (*Ambystoma cingulatum*). *Conserv. Biol.* 10:426-437.
- Mecham, J.S. and R.E. Hellman. 1952. Notes on the larvae of two Florida salamanders. *Quart. J. Florida Acad. Sci.* 15:127-133.
- Neill, W.T. 1954. Ranges and taxonomic allocations of amphibians and reptiles in the southeastern United States. *Publ. Res. Div. Ross Allen's Rept. Inst.* 1:75-96.

- Noss, R.F., E.T. LaRoe, III, and J.M. Scott. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. USDI Natl. Biol. Serv., Biol. Rep. 28:1-58.
- Palis, J.G. 1995. Larval growth, development, and metamorphosis of *Ambystoma cingulatum* on the Gulf Coastal Plain of Florida. *Florida Sci.* 58:353-360.
- Palis, J.G. 1996. Element stewardship abstract: flatwoods salamander (*Ambystoma cingulatum* Cope). *Nat. Areas J.* 16:49-54.
- Palis, J.G. 1997. Breeding migration of *Ambystoma cingulatum* in Florida. *J. Herpetol.* 31:71-78.
- Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L.J. Vitt, and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. *Science* 253:892-895.
- Peet, R.K. and D.J. Allard. 1993. Longleaf pine vegetation of the southern Atlantic and eastern Gulf Coast regions: a preliminary classification. In: S.M. Hermann (ed.) *Proceedings of the 18th Tall Timbers Fire Ecology Conference*, pp. 45-81. Tall Timbers Research, Inc., Tallahassee, Florida.
- Petranka, J.W. 1989. Density-dependent growth and survival of larval *Ambystoma*: evidence from whole-pond manipulations. *Ecology* 70:1752-1767.
- Platt, W.J., G.W. Evans, and M.M. Davis. 1988. Effects of fire season on flowering of forbs and shrubs in longleaf pine forests. *Oecologia* 76:353-363.
- Puri, H.S. and R.O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. *Florida Geol. Surv. Spec. Publ.* 5:1-312.
- Robbins, L.E. and R.L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. *Tall Timbers Research Sta. Misc. Publ.* 8:1-96.
- Schultz, R.P. and L.P. Wilhite. 1974. Changes in a flatwoods site following intensive preparation. *Forest Sci.* 20:230-237.
- Sekerak, C.M. 1994. Vegetation and aquatic vertebrate and macroinvertebrate assemblages in flatwoods salamander breeding ponds in the Apalachicola National Forest. Unpubl. M.S. Thesis, School of Forest Resources and Conservation, University of Florida, Gainesville, Florida.
- Torbert, J., L. Andrews, W.M. Aust, and J. Burger. 1993. Rotation age effects of drainage and fertilizer treatments on a wet pine flat in Virginia. In: J.C. Brissette (ed.) *Proceedings of the 7th Biennial Southern Silvicultural Research Conference*, pp. 247-250. Gen. Tech. Rep. SO-93. USDA Forest Service, Southern Experiment Station, Auburn, Alabama.
- USFWS. 1996. Endangered and threatened wildlife and plants: review of plant and animal taxa that are candidates for listing as endangered or threatened species, proposed rule. *Fed. Reg.*, 50 CFR Part 17, 61(40), 7596-7613.
- Wade, D.D. 1993. Societal influences on prescribed burning. In: S.M. Hermann (ed.) *Proceedings of the 18th Tall Timbers Fire Ecology Conference*, pp. 351-355. Tall Timbers Research, Inc., Tallahassee, Florida.
- Waldrop, T.A., D.L. White, and S.M. Jones. 1992. Fire regimes for pine-grassland communities in the southeastern United States. *Forest Ecol. Managem.* 47:195-210.
- Ware, S., C. Frost, and P.D. Doerr. 1993. Southern mixed hardwood forest: the former longleaf pine forest. In: W.H. Martin, S.G. Boyce, and A.C. Echternacht (eds.) *Biodiversity of the Southeastern United States*, pp. 447-493. John Wiley and Sons, New York, New York.
- Webb, S.D. 1990. Historical biogeography. In: R.L. Myers and J.J. Ewel (eds.) *Ecosystems of Florida*, pp. 70-100. University of Central Florida Press, Orlando, Florida.



# Effects of Slash Pine Silviculture on a Florida Population of Flatwoods Salamander

D. BRUCE MEANS,\* JOHN G. PALIS,†§ AND MARY BAGGETT‡

\*Coastal Plains Institute, 1313 N. Duval Street, Tallahassee, FL 32303, U.S.A., email dbm5647@garnet.acns.fsu.edu

†Florida Natural Areas Inventory, 1018 Thomasville Road, Suite 200C, Tallahassee, FL 32303, U.S.A.,

§RR1, Box 258, Tell City, IN 47586, U.S.A.

‡Department of Statistics, Florida State University, Tallahassee, FL 32306, U.S.A.

**Abstract:** *The largest known breeding migration of the flatwoods salamander (*Ambystoma cingulatum*) was monitored over a 22-year period following its discovery in 1970 in Liberty County, Florida (U.S.A.). Nightly migrations of 200–300 adults across a 4.3-km stretch of paved highway in 1970–1972 had dwindled to less than one individual per night in 1990–1992; the decline apparently was already underway in the 1980s. We discuss possible natural and anthropogenic causes of the decline. The silvicultural practice of converting native longleaf pine savanna to bedded slash pine plantation, implemented on our study site about 1968, may have interfered with migration, successful hatching, larval life, feeding, and finding suitable cover post-metamorphosis. Longleaf pine-wiregrass flatwoods inhabited by adults have been drastically reduced and severely degraded throughout the coastal plain and may explain why the species is rare and deserving of threatened status.*

El efecto de la silvicultura de claro de pino sobre una población de salamandra *Ambystoma cingulatum* de los bosques bajos de Florida

**Resumen:** *La más grande migración de crías conocida de la salamandra "flatwoods" (*Ambystoma cingulatum*) se siguió muy de cerca durante un plazo de 22 años después de su descubrimiento en 1970 en el condado de Liberty, Florida. Las migraciones nocturnas de 200–300 adultos en 1970–1972 a través de un tramo de 4.3 kilómetros de carretera pavimentada habían disminuido a menos de un individuo por noche en 1990–1992. Según parece, la disminución ya estaba en marcha en los años 1980. Deliberamos sobre posibles causas naturales y antropogénicas de esta disminución. La práctica silvicultural de convertir sabana de pinos "longleaf" autóctonos a plantío de pinos "slash" plantados se efectuó sobre nuestro sitio de estudio en 1968. Es posible que esta práctica haya afectado la migración, la salida de cascarón y la etapa larval de la salamandra, así como su alimentación y su habilidad de encontrar donde rirse después de la metamorfosis. Se han reducido en forma drástica y se han visto afectados los bosques de pino "longleaf" y pasto alambre donde viven los adultos. Estos hechos sirven como posible explicación de porqué la especie ya es rara y merece una clasificación como especie amenazada.*

## Introduction

A growing body of research shows that certain methods of timber harvesting have detrimental effects on salamander populations. In the Pacific Northwest of the United States, clearcutting reduces or eliminates popula-

tions of at least seven species of salamanders (Bury 1983; Brode and Bury 1984; Herrington & Larsen 1985; Corn & Bury 1989; Welsh 1990). Likewise in the southeastern U.S., clearcutting in mesic hardwood forests of the southern Appalachian Mountains has been shown to reduce or eliminate populations of at least 16 species of salamanders (Blymyer & McGinnes 1977; Ash 1988; Buhlmann et al. 1988; Petranksa et al. 1993). In the southeastern U.S. coastal plain, salamander population declines at

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tributed to logging have been claimed for one species in mesic hardwood forest (Jordan & Mount 1975; Dodd 1991) and for another in longleaf pine forest (Dodd 1993a).

Most of these studies were chronologically "horizontal" and compared salamander densities in old-growth forests to densities in variably aged stands of timber that had regenerated naturally or were replanted following clearcutting (e.g., Grant et al. 1994). Few declines in salamander populations following silviculture have been documented "vertically" over long periods of time. Most published studies have run only 2 to 4 years, and, compared to each other, they show variable population densities (Enge & Marion 1986; Pechmann et al. 1991; Raymond & Hardy 1991). The longest study reported no declines in six species of plethodontid salamanders monitored over 15–20 years in the southern Appalachians (Hairston & Wiley 1993). Long-term census data

of amphibian populations are urgently needed (Pechmann et al. 1991; Wake 1991).

The flatwoods salamander (*Ambystoma cingulatum*) inhabits fire-maintained, open-canopied longleaf pine (*Pinus palustris*) and slash pine (*P. elliottii*) savannas and flatwoods of the coastal plain of the southeastern United States (Goin 1950; Martof 1968; Anderson & Williamson 1976). Its breeding biology was detailed by Anderson and Williamson (1976). The species is an autumn breeder (Means 1972), fossorial after metamorphosis, rare in museum collections, and difficult to find in the field as metamorphosed adults. This reflects its conservation status as a species of special concern in Alabama (Means 1986), rare in Florida (Ashton 1992), endangered in South Carolina (Stephen Bennett, S. C. Department of Natural Resources, personal communication), and a Category 2 candidate for federal listing (U.S.

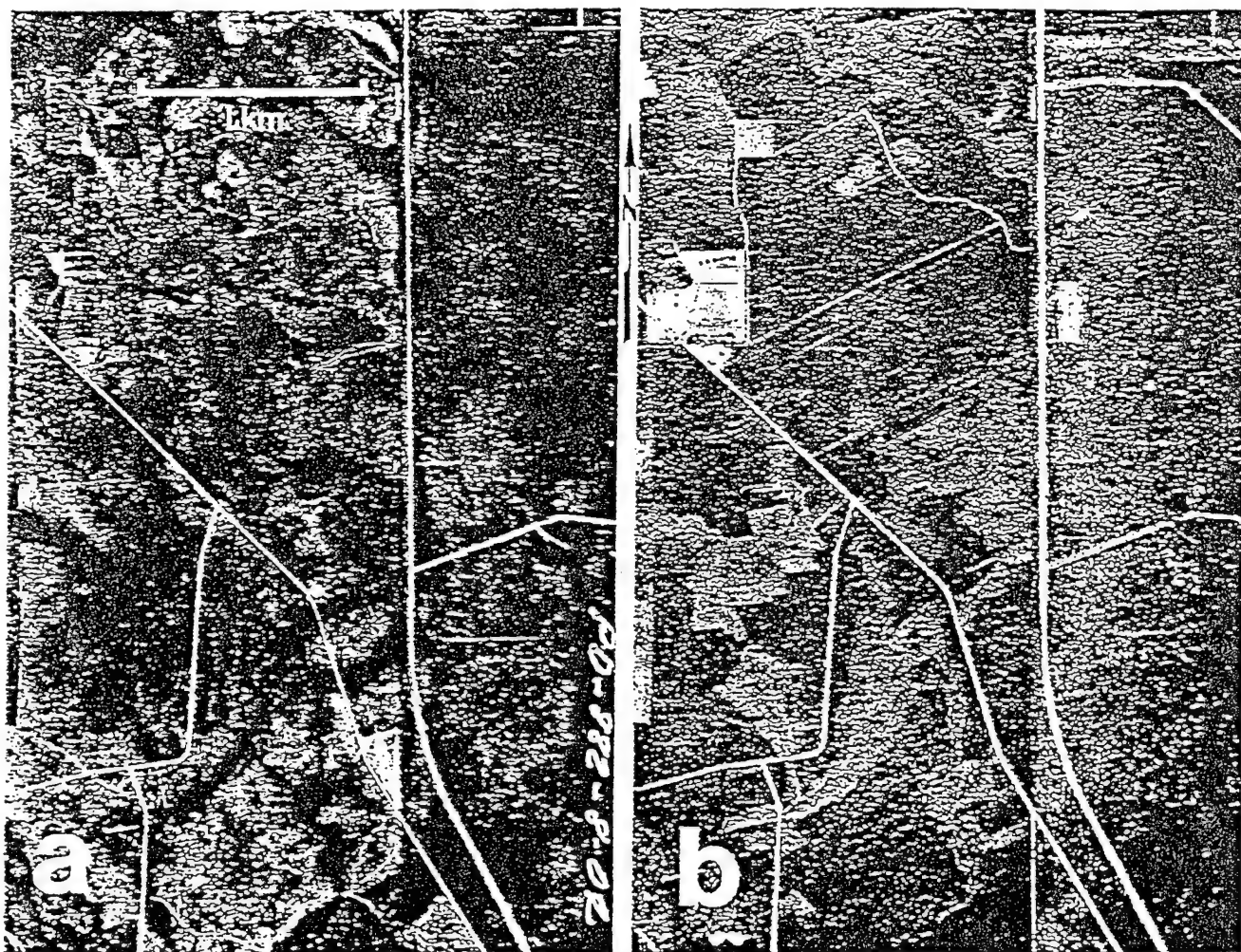


Figure 1. Aerial photographs of study areas, lands on both sides of a 4.3-km stretch of north-south running Florida Road C-12 (long, straight road bending east on its south end): the study site as it appeared on 5 October 1970 at the initiation of this study (a) and as it appeared 20 years later on 19 October 1990 (b). Camel Lake Road (National Forest Road 105) runs east from junction with C-12 in the southern half of the photographs. Lands east of C-12 are owned and managed by the U.S. Forest Service; lands west of C-12 are owned by a private timber company.

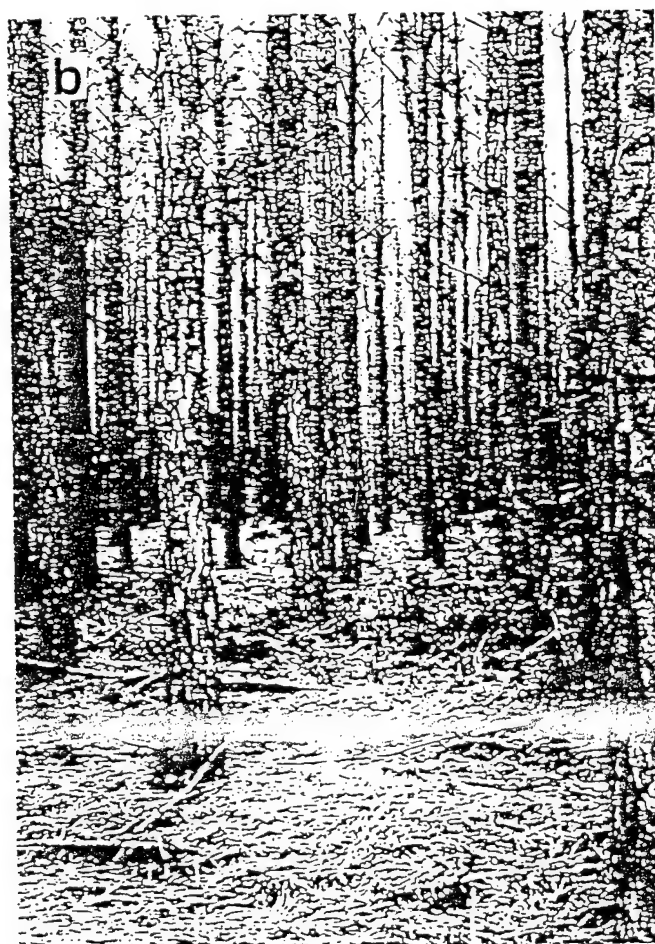
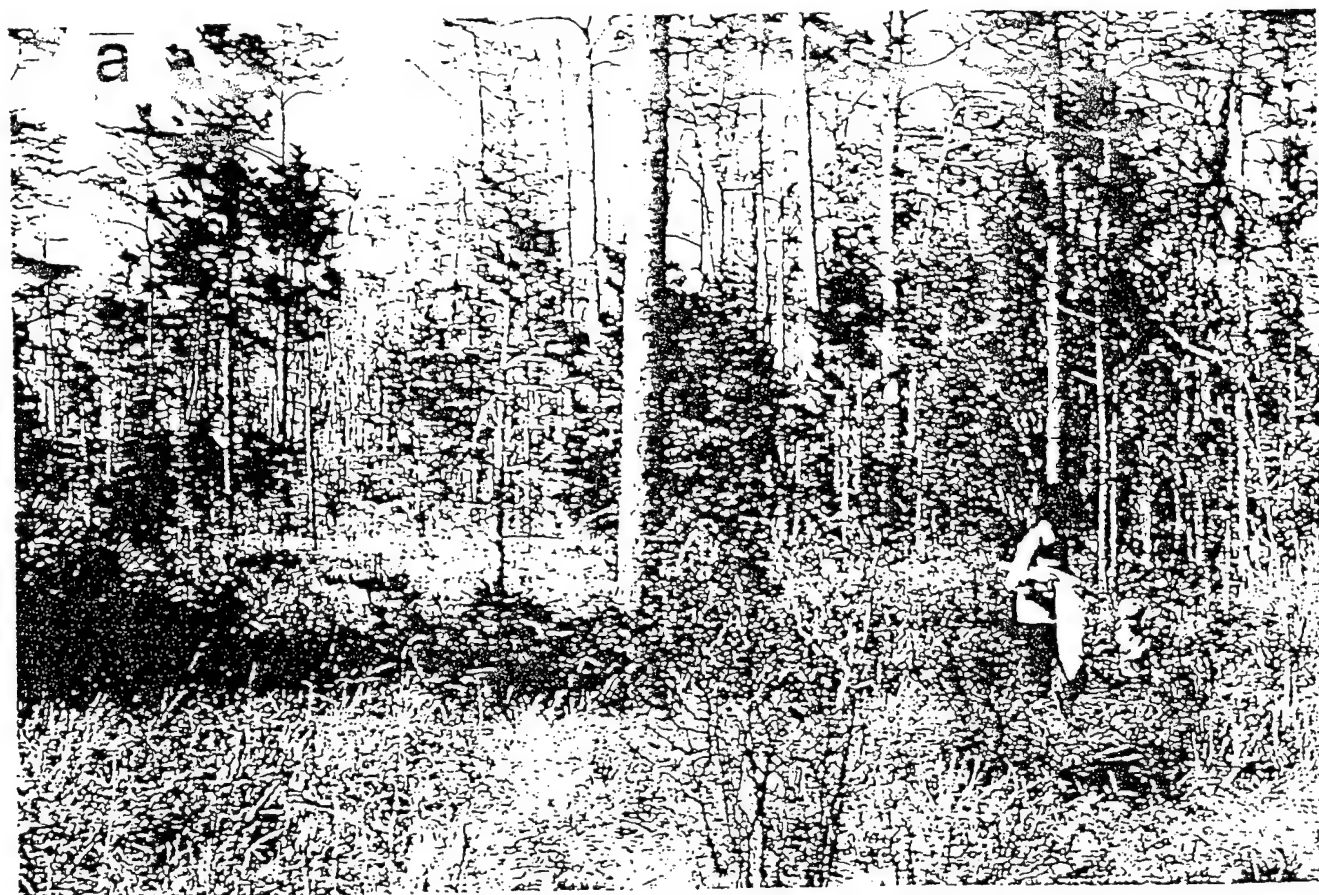






Figure 2. Habitat west of Florida Road C-12: a small, unbedded patch typical of the study area before silviculture 0.1 km north of the junction of Camel Lake Road (National Forest Road 105) as it appeared on 30 November 1971 (photo by D. B. Means) (a); closed-canopy, bedded slash pine plantation representative of most of the study site west of C-12 on 22 October 1991 (photo by J. Palis) (b); and after mechanical site preparation the second time on 22 May 1993 (photo by D. B. Means) (c).

Fish & Wildlife Service 1994). Elsewhere in Georgia, Louisiana, and Mississippi the flatwoods salamander is generally considered rare, and some old locality records are in doubt (Dodd 1993b).

In 1970 Means (1972) discovered the largest known breeding migration of the species along a 4.3-km stretch of paved highway in the Florida panhandle. More than 20 years later this population has declined nearly to extinction. This is the second report of the decline of a species of salamander in the longleaf pine forest ecosystem of the coastal plain (Dodd 1993a) and the first documentation of the decline of an amphibian population monitored over a period of more than two decades. We conclude that silviculture practices are the probable cause of decline in our study area.

### Study Site and Methods

Lying in the coastal lowlands physiographic province of Florida panhandle (Puri & Vernon 1964), the study site

(Fig. 1) is situated about 14.5 km south-southwest of Bristol, Liberty County, on an ancient, abandoned terrace of the Apalachicola River. It is 15–17 m in elevation, about 6.0–7.5 m above the level of the present floodplain, well above the annual high water of the river and about 2.0 km east of the present channel of the river. The study site consisted of a strip of land about 1.5 km wide and bisected by a 4.3-km stretch of Florida Road C-12. Road C-12 runs north-south along the western boundary of the Apalachicola National Forest (ANF) down the section line common to sections 22 and 23, 26 and 27, 34 and 35, T2S R8W. The study site begins at the extreme northwestern corner of ANF and ends on the south and east at Little Gully Creek.

Salamanders were observed as we drove after dark at 15–40 kph during or immediately following precipitation. During the period 1968–1970, one of us determined that rains accompanying the passage of a cold front in October and November stimulated the main breeding migrations in this species (Means 1972). Data on salamander occurrences were gathered from three

series of field trips over a 22-year period: 10 trips by D. B. Means between 29 October 1970 and 27 October 1972; 5 trips by D. B. Means between 27 October 1980 and 15 November 1989; and 12 trips by D. B. Means and J. G. Palis between 7 January 1990 and 10 December 1992. When possible, we noted the direction of movement of each live specimen we observed.

Using a Jonckheere test, we tested the hypothesis that there were no changes among the three groups of census data. Using binomial probabilities, we tested the hypothesis that there were no differences in the number of salamanders moving east and west for October migrations in the years 1970–1972 and for all October dates combined.

To test whether rainfall changed during the 22-year period of this study, we compared precipitation data gathered by the U.S. Weather Bureau at Apalachicola, Florida, about 70 km south of our study site, among the three sets of years for the months of our observations (Fig. 3). We were unable to use data from nearby Bristol, which is incomplete after 1985.

We determined the land-use history of the study site from aerial photographs (1937, 1967, 1970, 1975, 1982,

1983, 1990, 1993), soil surveys (U.S. Forest Service and the Soil Conservation Service), records on file with the U.S. Forest Service, interviews with ex-employees of a private timber company that owns the lands in the western half of our study site, and our own observations during more than two decades. Land east of the road has been owned and managed by the U.S. Forest Service since 1936. Land on the west side has been owned and managed by a privately owned timber company since 1952.

Aerial photographs from 1937 show that the entire site on both sides of C-12 was rather uniform vegetatively. Four types of vegetation are recognizable in these aerials: (1) nearly treeless wet savanna dominated by graminoids, especially wiregrass (*Aristida stricta*), pine-woods bluestem (*Andropogon arctatus*), Florida dropseed (*Sporobolus floridanus*), and toothache grass (*Ctenium aromaticum*); (2) mesic longleaf pine flatwoods; (3) depressions dominated by pond cypress (*Taxodium ascendens*); and (4) low-gradient stream courses vegetated with evergreen shrubs such as swamp titi (*Cyrilla racemiflora*), tall gallberry (*Ilex coriacea*), myrtle-leaved holly (*I. myrtifolia*), and sweet bay (*Magnolia virginiana*).

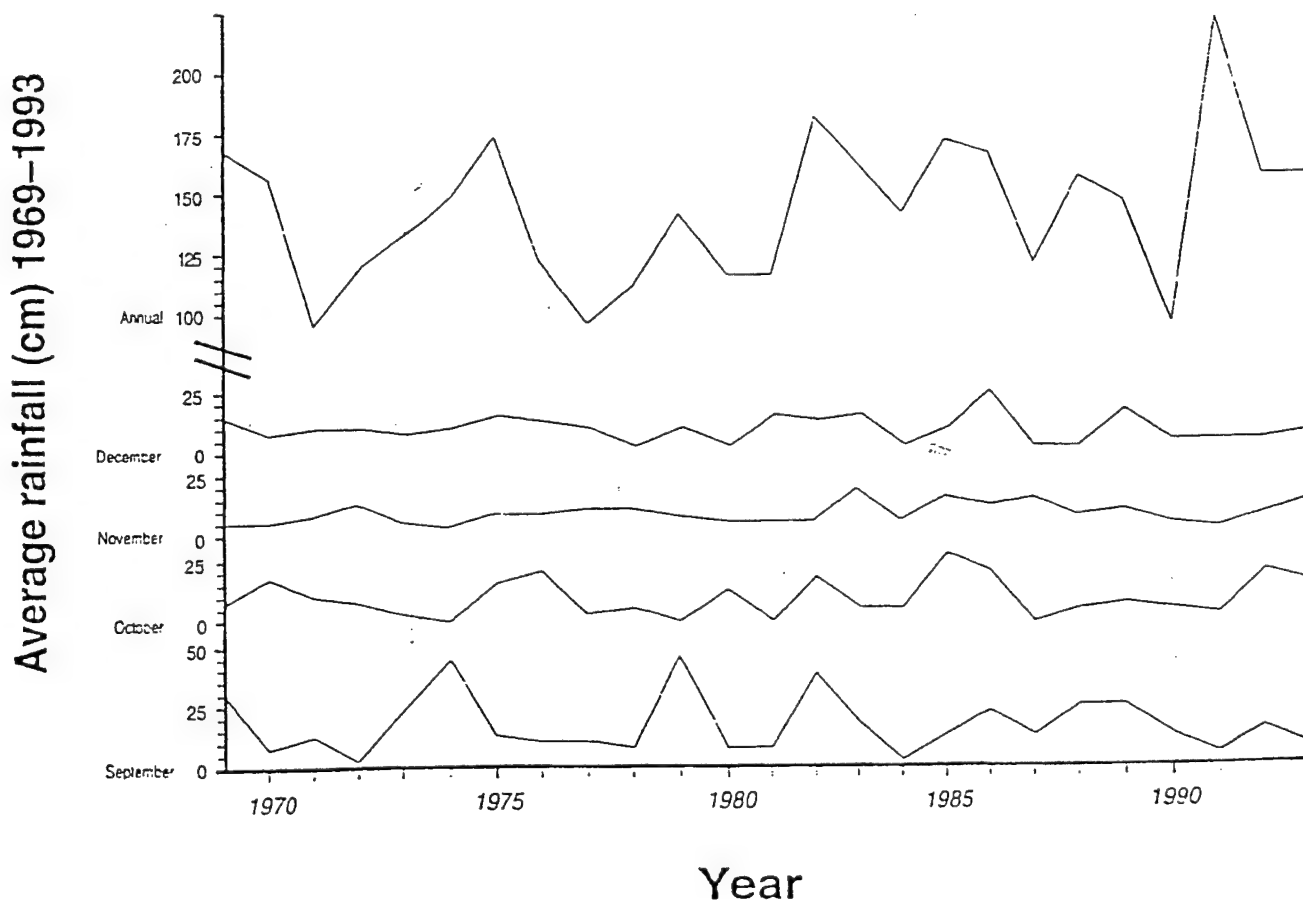


Figure 3. Rainfall data for the months of September through December and annual rainfall over a 25-year period of record at U.S. Weather Bureau station at Apalachicola, Florida.

ana), sometimes mixed with pond cypress and black gum (*Nyssa sylvatica* var. *biflora*). Except for cypress depressions, riparian forest in watercourses, and scattered pines visible in flatwoods, the 1937 aerial photographs indicate that much of the study site was nearly devoid of trees and probably consisted of type 1 and cutover type 2 vegetation.

The death of trees in the 1937 aerial photographs can probably be explained in two ways. First, longleaf pine in the mesic flatwoods was cut during widespread regional logging in the 1930s. Second, more than 50% of the study area contains loamy soils with high clay content of the Bladen, Plummer, Dunbar, Rutledge, and Dothan series, which today underlie large, wet, treeless savannas throughout the Apalachicola Ranger District of the ANF (U.S. Forest Service 1984; special soil survey conducted for this study by Soil Conservation Service). Wet savannas support most of the presently known breeding ponds of the flatwoods salamander populations on the ANF (J. G. Palis, unpublished data). Longleaf pine flatwoods and wet savannas experienced frequent fires during the lightning season from May to August. The fact that the 1937 aerial photographs show the floodplain of Little Gully Creek also to be nearly devoid of woody vegetation attests to the high frequency of fires on the study site at that time.

Another reason for the sparse timber may have been annual winter burning, a common practice in Florida during the days of free-ranging livestock. Even seedlings of the fire-resistant longleaf pine are unable to cope with frequent winter fires (Wahlenberg 1946). The 1937 aerial photographs also show extensive cattle trails in the savanna habitat.

Since 1937, the privately owned land on the west side of C-12 has had a very different history of land use than the ANF land on the east side. Almost all of the ANF land was planted by hand to slash pine (*Pinus elliottii*) in 1941 on sites that were naturally longleaf pine sites. A very small remaining area was hand-planted in 1954. None of the ANF land was treated with mechanical site preparation. To protect the sapling pines the ANF plowed a series of deep, parallel fire lines along the national forest boundary to keep out the annual winter fires started by ranchers in the wet savanna lands under private ownership to the north and west. On the northern boundary of the ANF tract, three sets of fire lines were constructed about 100 m apart; these consisted of six, four, and two parallel fire lines. Immediately west of C-12 the U.S. Forest Service plowed six parallel fire lines. In the 22-year period of our study, the ANF property was prescription-burned six times (David Farnsworth, personal communication). Aside from timber-thinning operations and the removal of lighterwood stumps, the land on the ANF side of C-12 has had no major disturbance of the timber or the groundcover during the past 50 years. The slash pine and mixed slash-longleaf pine

stands of 40–55 years of age are physiognomically nearly identical to equivalently aged, second-growth longleaf pine forests elsewhere on the ANF, and the native wiregrass groundcover is intact.

The privately owned land on the west side of C-12 remained unmanaged until about 1970. Aerial photographs from 1967 show that in general it had few trees and was wet savanna with scattered cypress depressions and cutover mesic flatwoods, similar to its condition in aerial photographs taken immediately after bedding in 1970 (Fig. 1a). Some expansion of hardwood shrubs out of swamps and stream courses probably resulted from the suppression of wildfires. The open condition of the site (except for cypress depressions) in 1937 is still evident in a small patch of unbedded land in 1970 and 1971 (Figs. 1a & 2a).

In 1970, however, just before this study began, the savanna lands west of C-12 experienced gross physical and biological alteration. All but the wettest ponds were roller-chopped, mechanically bedded, and planted to slash pine. Over the following decade these slash pine plantations became choked with a subcanopy of dense evergreen shrubs, principally gallberry (*Ilex glabra*) and tall gallberry (*I. coriacea*). Hardwood invasion was probably facilitated by exposure of a bare mineral soil seed bed and exclusion of control burns and wildfires. The densely stocked slash pines achieved canopy closure by about 1980 and were not thinned (Figs. 1b & 2b).

In 1991 the privately owned timberlands west of C-12 underwent a second upheaval. The slash pines were clearcut, and the entire site was bedded to bare soil and replanted to slash pines for the second time in about 20 years (Fig. 2c).

## Results

Over a 22-year period, 1970–1992, the number of migrating flatwoods salamanders encountered on our study site declined severely. Table 1 displays the three sets of data we generated. In 16.5 hours over 10 trips in the autumns of 1970–1972, we observed 130 flatwoods salamanders. Differences in the numbers of individuals seen per trip probably were the result of differences in the amount and nightly temporal distribution of rainfall. For instance, between 2030 and 2300 hours on the night of 14 November 1970, we found 7 individuals in 2.5 hours; the rain had stopped falling at 2000 hours, and the sky had cleared. In comparison, in one hour during a steady rain on the night of 9–10 October 1971, we observed 36 individuals. Our encounter rate in the period 1970–1972 was 7.9 individuals per hour. During the 1980s we made 9 trips in optimal migrating weather and season but observed only 10 individuals in 17.5 hours (0.6 individuals/hour). We suspected that a decline had taken place, so from 1990 to 1992 we made a deter-

Table 1. Number of flatwoods salamanders encountered per census migrating across a 4.3-km stretch of highway in Liberty County, Florida, 1970-1992.

	1970-1972		1980-1989		1990-1992	
	Survey hours	Number seen	Survey hours	Number seen	Survey hours	Number seen
	0.50	2	1.00	1	1.00	0
	2.00	8	2.00	1	3.25	1
	2.50	7	3.00	3	3.50	0
	1.25	6	2.50	4	3.50	1
	1.00	36	1.50	0	1.50	0
	1.00	0	1.50	1	2.00	0
	1.00	4	1.00	0	0.50	0
	1.25	13	3.00	0	2.25	0
	3.00	23	2.00	0	0.50	0
	3.00	31			0.50	0
					1.00	0
$\Sigma \Sigma$	16.50	130	17.50	10	20.00	2
No. trips		10		9		12
$\bar{x}$ individuals/hour		7.9		0.6		0.1

mined effort to conduct road surveys during each autumn rain; 20 hours of census time on 12 different trips yielded only 2 flatwoods salamanders (0.1 individual/hour). The decrease in the overall encounter rate from the 1970s to the 1990s was almost 99%. We rejected the hypothesis that there was no difference in the numbers of flatwoods salamanders observed between the 1970-1972, 1980-1989, and 1990-1992 censuses against the alternative that numbers declined among the three groups ( $p < 0.0001$  level [Jonckheere test]).

It was obvious during the October censuses of 1970-1972 that most of the adults in breeding condition (89%) were moving east to west across C-12 from longleaf pine wiregrass flatwoods of the ANF onto private timberland (9-10 October 1970: 30 went west and 6 went east; 23-24 October 1971: 20 went west and 2 went east; 27-28 October 1972: 29 went west and 2 went east). The hypothesis that the animals were migrating in both directions on the three October dates was rejected at  $p < 0.0001$ . Later, in December, small numbers of post-breeding flatwoods salamanders were encountered as they returned eastward to upland pine forest habitat. On 21 December 1971, D. B. Means recorded that all but one of the eight live adults were headed west to east, reversing the direction of migration noted on the night of 9-10 October. These individuals were greatly emaciated compared to the salamanders examined on 9-10 October.

From 1970-1972, when we observed 130 migrating individuals in 10 trips, there was ample rainfall (2.5-7.0 cm) in the months of October and November, even though annual rainfall for 1971 was just 68% of the 25-year rainfall average (143.9 cm) for the period 1969-1993 (Fig. 3). During the period 1990-1992, when we observed only two individuals in 12 trips, there was ample rain in 1990 and 1992. Ironically, in the all-time wet

year of 1991 when 224.0 cm were recorded at Apalachicola, rains during October and November were scant, less than 2.54 cm per month. Rainfall data for 1991 recorded at Bristol, only 14.5 km north-northeast of our study site, were 2.40 cm for October and 5.54 cm for November. We are not sure whether rains in October and November of 1991 were sufficient to have stimulating breeding migrations in that year, but, overall during the period 1990-1992, the evidence does not support annual or seasonal drought as the cause of the long-term decline we observed in this population (Fig. 3).

Using a Kruskal-Wallis test, we found no significant differences ( $p = 0.32$ ) in rainfall among the three groups of autumns of our study. The differences were even less significant ( $p = 0.84$ ) when we repeated the analysis with the three time groups combined. A regression analysis was used to detect any long-term trend in the annual rainfall from 1969 through 1993. This suggested a small, positive, though insignificant ( $p = 0.20$ ), slope. We conclude that there was no overall trend in annual rainfall during the 22 years of our study.

## Discussion

The decline of the flatwoods salamander we witnessed may have taken place over 10 generations or less. The salamander has the capability in captivity of reaching adult size in one year (Means 1972), but true generation time may be two or more years. As evidence for this, one of us collected many small, immature, terrestrial individuals that had retained their larval striping during fall migration on a study site in Okaloosa County, Florida, in 1993 (J. G. Palis, unpublished data).

Stochastic events can be the cause of a population de-



cline in 10 generations even when the decline is transient (Pechmann et al. 1991; Travis 1994). Natural declines in other species of *Ambystoma* have been measured over periods of much less than one decade, but the magnitude of these declines was not nearly as severe as the decline we recorded (Shoop 1974; Semlitsch 1983; Harte & Hoffman 1989). The decline we witnessed may not have been monotonic (continuously decreasing) because our data were gathered in several-year intervals with gaps during the 22-year period, but such a severe overall decline in 5–10 generations seems highly unlikely under natural conditions. In our opinion the magnitude of the decline we observed demonstrates that the population constituting the breeding migration across C-12 is essentially extinct.

There are many possible natural and anthropogenic causes of the decline in flatwoods salamanders migrating across Florida C-12 over 22 years. Chief among the natural causes is drought, either long-term or seasonal, which could affect the availability of the temporary ponds used by the salamander to lay eggs and live through a 3- to 4-month larval stage. Rainfall data and our field observations, however, clearly reject drought as a cause of the decline. We find no evidence for other types of natural causes that might explain the decline.

Possible anthropogenic causes of the decline of our study population include highway mortality during breeding migrations and pollution of the habitat of the larvae or metamorphs. We did not notice enough increased traffic in 22 years to be convinced that highway mortality is severe. Highway C-12 is one of the least populated stretches of paved road in northern Florida. Our C-12 study site lies far from the closest settlement to the north, the small hamlet of Bristol, with a population of 937 in 1990. South of our study site, C-12 extends another 15 km through the uninhabited ANF to Wilma, population 12. From Wilma, Florida Road 65 runs 53 km to the Gulf of Mexico between East Point and Carabelle. The principal traffic on C-12 is during the day—loggers and other people working on ANF. When breeding migrations were underway on cold, wet, autumn nights, fewer than five cars per hour passed over the study stretch after about 2100 hours, and we observed very few road-kills. We do not believe that mortality from cars, therefore, explains the decline we have documented. Also, we have not observed scientific or pet-trade collecting because, until now, we have zealously refrained from giving out information about this breeding site.

Our own collecting was limited to 10 small series, including road-kills and totalling 73 specimens during all the years of this study. During the period 1970–1972 we often left the field after verifying that migration was underway. On some nights, such as 9–10 October 1971, one of us (D. B. Means) recorded in his field log, "If this migration lasted all night (and I suspect that it did) there were 200–300 adults moving across the road. . . ."

Northern Florida has experienced a marked increase in acid rainfall since 1955 and now receives from one-third to one-half of the deposition of  $H^+$  that the heavily affected northeastern United States receives (Brezonik et al. 1980). We do not expect acidification of the larval habitat, however, to be an important factor in the population decline we witnessed because waters of the cypress breeding ponds used by *Ambystoma cingulatum* are normally highly acidic, with an average pH of 4.3, range 3.7–5.3 (J. G. Palis, unpublished data). In support of this belief, one of us (J. G. Palis) has documented successful reproduction by *Ambystoma cingulatum* in 40 wetlands within 40 km of our study site, during the time period 1990–1994.

One anthropogenic impact on the study site, economic forestry, is so obvious and severe that we believe it alone to be responsible for the 22-year decline. We do not know exactly how slash pine silviculture has affected our study population, but both the aquatic habitats of larvae (breeding ponds) and the terrestrial habitats of recent metamorphs and adults (flatwoods vegetation) have been severely affected.

We observed heavy sedimentation from surface runoff into breeding ponds west of C-12, but because we have taken larvae from breeding ponds on both sides of C-12 in the 1990s in spite of the severe decline in the breeding migration, we know that a small breeding population has survived on each side of the road. Neither the breeding ponds nor the terrestrial habitat east of C-12 have been affected as severely as the lands and ponds west of C-12, so it is not surprising that there are larvae in the small ponds on the east side. The presence of larvae in ponds west of C-12 may be explained, however, by a 1-ha patch of savanna excluded from slash pine silviculture, which provides a small amount of habitat for adults. Alternatively, a few salamanders may survive in the bedded slash pine habitat adjacent to these ponds.

Mechanical alteration of the terrestrial habitat may be responsible for the 22-year decline. We see no obvious evidence of disturbance of the adult habitat east of C-12, the ANF side, that might have caused the severe decline of migrating adults that we witnessed. In 22 years the only ecological conditions that have changed on the ANF side have been an increasing closure of the mixed longleaf and slash pine canopy (Fig. 1b), but by late 1970 the privately owned land west of C-12 was roller-chopped, bedded, and planted with slash pine. Bedding was accomplished by deeply plowing the topsoil into long parallel ridges. A common practice in wet soils, bedding elevates the newly planted trees in order to decrease the time that roots are inundated. For animals and plants adapted to the hydrology of wet savannas, bedding creates elevated, drier soils on the tops of the beds and wetter soils in the trenches between the beds. The original hydrological conditions of the site are dramatically altered (Schultz & Wilhite 1974). Savanna ground-

cover plants are uprooted and buried in the overturned topsoil, and the entire infrastructure of the soil (roots, burrows) is destroyed.

Over the years following bedding we observed three vegetative changes taking place on the west side of C-12 (Figs. 1a versus 1b; 2a versus 2b). First, there was a drastic reduction of the native perennials and a pronounced increase of weedy colonizing plants such as broomsedge (*Andropogon virginicus*), dogfennels (*Eupatorium* spp.), and blackberry (*Rubus cuneifolius*), which changed the dominance relationships of the species of groundcover flora—more weedy species, fewer native specialists. Second, because the site was protected from fire for more than two decades, woody plants such as gallberry, tall gallberry, myrtle-leaved holly, greenbrier (*Smilax* spp.), muscadine (*Vitis rotundifolia*), yellow jessamine (*Gelsemium sempervirens*), and swamp titi increased their dominance on the site through time, at the expense of the annuals and herbaceous perennials. And third, as the slash pines grew, the overstory canopy closed within about 10 years, creating dense shade that this site had not known probably for millennia (Figs. 1b & 2b).

These forestry practices could have had several possible negative effects on *Ambystoma cingulatum*. The physical alteration of the ground surface by bedding may have interfered with the orientation of flatwoods salamanders during migration. Although nothing is known about the physical cues utilized by flatwoods salamanders migrating in and out of ponds, there is no natural analog of the regular ridges and swales created by the parallel beds on which slash pines are planted. Migrating along an increasing moisture gradient in gently inclined flatwoods terrain, such as probably happens in natural circumstances, is precluded by a gridwork of earthen ridges. Because beds do not extend out radially from flatwoods breeding ponds, migrating adults could be disoriented and deflected away from their breeding ponds by the alternating ridges and swales lying at angles to their path.

In Florida, *Ambystoma cingulatum* normally oviposits in the broad, grassy upper zone of flatwoods depressions that fill incrementally (Palis, personal observation). When this short-hydroperiod zone is mechanically bedded, females may be forced to lay eggs in the inter-bed furrows, which do not permit larvae to follow receding water to safety during drying. Or, females may have laid eggs on top of beds, above the level of inundation.

Emigrating metamorphs are the next life stage that could be affected by site alteration. In unaltered wet savanna habitat metamorphs leaving the pond move into a dense grassland, the soil of which is riddled with crayfish burrows and root channels. The dense groundcover buffers changes in microclimate, and the crayfish burrows and root channels provide shelter (Neill 1951; Ashton 1992). Bedding, however, eliminates much of the vegetative cover for the first year or two and destroys

subterranean passages. Such changes could result in reduced survival of metamorphs.

There may be factors associated with the virgin condition of the groundcover that are vitally important to flatwoods salamanders. The effects of mechanical site preparation and closure of the planted pine canopy on the soil-inhabiting invertebrate fauna, which serves as food for post-metamorphic individuals, are unknown. Local extirpation of their prey could result in the starvation of the metamorphs. One invertebrate predator, the exotic fire ant (*Solenopsis invicta*) increases as a result of site disturbance (Tschinkel 1993). Flatwoods salamander metamorphs could be vulnerable to predation by fire ants, although data to demonstrate this are lacking.

Ashton (1992) reported that some radioactivity tagged flatwoods salamanders moved up to 1700 m away from a breeding pond. In our experience, the ability to disperse 1700 m would enable the flatwoods salamander to reach several breeding ponds in flatwoods terrain, but nothing is known about breeding-site fidelity in this species. If breeding-site fidelity is high there is little chance that adults will go elsewhere to breed in the event that a pond is polluted or destroyed or that immigration from other ponds could restock ponds in which the breeding population is extinct. As more flatwoods area is destroyed and rendered unsuitable, the density of suitable breeding ponds will be lower, the journey between ponds harsher, and the rate of recolonization reduced (Travis 1994). This is one scenario that seems to fit our study example.

If silviculture alterations of the upland habitats utilized by the flatwoods salamander are at least partly responsible for the decline we have observed in migrating salamanders on our study area, then studies to determine upland habitat utilization by the flatwoods salamander are urgently needed for two reasons. First, we believe that early statements about the association of the adult flatwoods salamander with slash pine are misleading and could result in an incorrect conclusion that slash pine silviculture is beneficial to the species. Second, silviculture and other anthropogenic impacts on the native flatwoods habitat have been so severe that they may explain the present rarity of the species throughout its geographic range.

The earliest definitive description of the terrestrial habitat of the flatwoods salamander is that of Goin (1950), who said that, "Both races of *A. cingulatum* seem to be essentially inhabitants of slash pine-wire grass flatwoods." Field guides thereafter echoed this statement (Conant 1958; Cochran & Goin 1970; Smith 1978; Conant & Collins 1991). Goin's description is misleading because all the specimens available to him were collected in the breeding and larval habitats (Martof 1968), and, at the very least, slash pine flatwoods provide only a small fraction of the habitat occupied by adult flatwoods salamander. Goin (1950) clarified this

himself: "Every specimen for which detailed ecological notes are available was taken in or near one of the small, shallow, cypress ponds so characteristic of these flatwoods or in a drainage area from such a pond."

The present-day habitat distribution of slash pine is very different from its presettlement distribution, so it is important to clarify how the distribution of slash pine has changed and to clearly understand where the flatwoods salamander lives in the mosaic of natural vegetative communities in flatwoods. Clewell (1971) stated that slash pine is native to three general habitats in the panhandle of Florida. The first is on barrier islands and in a fringe of up to several hundred yards inland from the Gulf coast. The second is acid swamps such as bay swamps and non-alluvial floodplains of blackwater streams. The third is the wetter portion of pine flatwoods and associated seepage bogs, especially near bay swamps and cypress strands. Only this third type of habitat applies to the flatwoods salamander, which probably never occurred in the first two. Of this latter habitat Roth (in Mohr 1897) said that between the Apalachicola and Suwannee rivers slash pine comprised only about 15% of the trees in flatwoods, which consisted otherwise of longleaf pine (Clewell 1971). By the 1990s the native habitats of slash pine have been obscured by slash pine plantations and by the widespread invasion of slash pine into longleaf pine habitats, where the natural fire frequency has been reduced by human activities (Clewell 1971).

Our observations indicate that the adult flatwoods salamander is primarily an inhabitant of longleaf pine-wiregrass flatwoods and that slash pine flatwoods form only a small proportion of the adult habitat. Ash-ton's (1992) finding of movements of more than 1700 m away from breeding ponds corresponds with distances

of 300–500 m that our study animals must have moved through longleaf pine flatwoods to reach breeding ponds in cypress depressions west of C-12. Movements of these magnitudes are consistent with our hypothesis that adults live largely in longleaf pine-wiregrass flatwoods up to 500 m or more from breeding ponds.

Originally, longleaf pine forests were the predominant upland habitat type in the Coastal Plain from North Carolina to east Texas, comprising more than 33,000,000 ha (Wahlenberg 1946; Ware et al. 1993). Ware et al. (1993) have calculated that the fire-maintained plant communities (longleaf pine forest) of their Southern Mixed Hardwood Forest Region (essentially the coastal plain) fell drastically from 60.6 to 1.4% of the upland landscape of the region from presettlement times to 1990 (Table 2). By 1990 longleaf pine remained on only about 776,000 ha (Ware et al. 1993), representing a shrinkage from 93 to 2% of the original longleaf pine distribution in about 200 years. Less than 3,900 ha (~0.01%) remain with old-growth trees more than 300 years old in scattered blocks of varying acreages (Means 1996). These native forests were largely replaced by successional forests, pine plantation, pasture, cropland, and developed land—all ruderal habitats created by humans (Table 2).

Large timber corporations began establishing pine plantations in the longleaf pine belt in the 1940s (Ware et al. 1993). At present in the southeastern U.S., there are about 6,202,000 ha of pine plantations, composed primarily of slash and loblolly pines (Ware et al. 1993). In Florida approximately 90% of all forests occur on commercial forest land (Kautz 1993). During the last 51 years, longleaf pine forest has been reduced by 88% on commercial forest land in Florida (Kautz 1993). By 1987 slash pine accounted for 69% of all commercial pine forest (Kautz 1993) in Florida, with 63% of it in plantations.

Table 2. Distribution of natural and ruderal vegetation in 345 counties of the southern mixed hardwood forest region (Ware et al. 1993) of the southeastern United States.

Vegetation*	ha (× 1000)		Distribution (percentage of region)	
	Presettlement	1990	Presettlement	1990
Longleaf pine	22,372	388	40.4	0.7
Mixed pine-hardwood	11,187	388	20.2	0.7
Upland slash pine	1,440	222	2.6	0.4
Southern mixed hardwood forest	1,108	222	2.0	0.4
Wetlands	19,272	13,955	34.8	25.2
Successional forests	0	17,444	0	31.5
Pine plantation	0	6,202	0	11.2
Pasture	0	2,990	0	5.4
Cropland	0	9,359	0	16.9
Developed	0	4,209	0	7.6
Totals	55,379	55,379	100	100

\* Longleaf pine: natural, fire-maintained savanna and woodland savanna and woodland; mixed pine-hardwood: natural, fire-maintained mixed pine-hardwood savanna and woodland; upland slash pine: natural, fire-maintained slash pine on uplands; southern mixed hardwood forest: dominated by beech, southern magnolia, other hardwoods, and semievergreen oaks; successional forests: mixed pine-hardwood forests resulting from logging, old-field abandonment, and fire exclusion.

Slash pine plantations were established in place of longleaf pine on mesic flatwoods sites such as those inhabited by *Ambystoma cingulatum*. Should present trends continue nearly all southeastern uplands owned by timber companies will have been converted to plantations at the end of the present rotation (Ware et al. 1993).

If we are correct that slash pine silviculture is in some way responsible for the decline of what was once a large breeding migration of the flatwoods salamander on our study area, then silvicultural practices may explain why the geographic distribution of *Ambystoma cingulatum* today appears to be fragmented and why known populations seem to be declining or extinct. In the future it is likely that *Ambystoma cingulatum* will be increasingly restricted to remnant longleaf pine forests occurring on public and private conservation lands as the species is extirpated from privately owned commercial timber lands whose native groundcover has been mechanically disturbed and excessively shaded by densely stocked tree plantations.

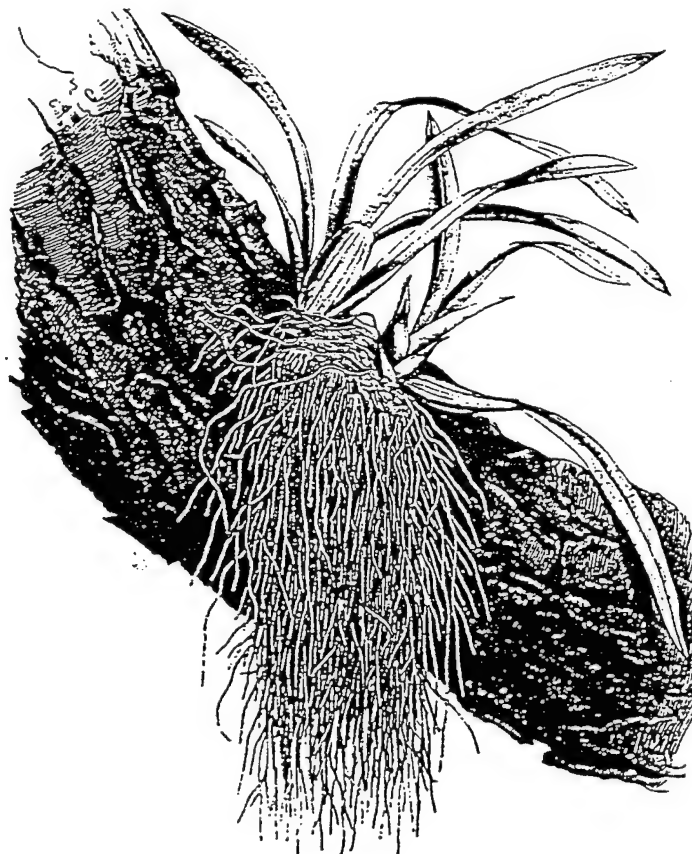
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## Literature Cited

- Anderson, J. D., and G. K. Williamson. 1976. Terrestrial mode of reproduction in *Ambystoma cingulatum*. *Herpetologica* 32:214-221.
- Ash, A. N. 1983. Disappearance of salamanders from clearcut plots. *The Journal of the Elisha Mitchell Scientific Society* 104:116-122.
- Ashton, R. E., Jr. 1992. Rare: flatwoods salamander. Pages 39-43 in P. Moler, editor. *Rare and endangered biota of Florida*, volume 3. Amphibians and reptiles. University Presses of Florida, Gainesville.
- Blymyer, M. J., and B. S. McGinnis. 1977. Observations on possible detrimental effects of clearcutting on terrestrial amphibians. *Bulletin of the Maryland Herpetological Society* 13:167-178.
- Brezonick, P. L., E. S. Edgerton, and C. D. Hendry. 1980. Acid precipitation and sulfate deposition in Florida. *Science* 208:1027-1029.
- Brode, J. M., and R. B. Bury. 1984. The importance of riparian systems to amphibians and reptiles. Pages 30-36 in R. E. Warner and K. E. Hendrix, editors. *Proceedings of the Conference on California Riparian Systems*. University of California, Davis.
- Buhlmann, K. A., C. A. Pague, J. C. Mitchell, and R. B. Glasgow. 1988. Forestry operations and terrestrial salamanders: techniques in a study of the Cow Knob salamander, *Plethodon punctatus*. Pages 38-44 in R. C. Szaro, K. E. Severson, and D. R. Patton, editors. *Management of amphibians, reptiles, and mammals in North America*. Technical report RM-166. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.
- Bury, R. B. 1983. Differences in amphibian populations in logged and old growth redwood forests. *Northwest Science* 57:167-178.
- Clewell, A. F. 1971. The vegetation of the Apalachicola National Forest: an ecological perspective. Contract 38-2249, Final Report. U.S. Forest Service, Atlanta, Georgia.
- Cochran, D. M., and C. J. Goin. 1970. *The new field book of reptiles and amphibians*. G. P. Putnam's Sons, New York.
- Conant, R. 1958. *A field guide to reptiles and amphibians of the United States and Canada*. Houghton Mifflin, Boston.
- Conant, R., and J. T. Collins. 1991. *A field guide to the reptiles and amphibians of eastern and central North America*. Houghton Mifflin, Boston.
- Corn, P. S., and R. B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. *Forest Ecology and Management* 29:39-57.
- Dodd, C. K., Jr. 1991. The status of the Red Hills salamander *Phaeognathus hubrichti*. Alabama USA, 1976-1988. *Biological Conservation* 55:57-75.
- Dodd, C. K., Jr. 1993a. Distribution of striped newts (*Notophthalmus perstriatus*) in Georgia. U.S. Fish and Wildlife Service, Jacksonville, Florida.
- Dodd, C. K., Jr. 1993b. Amphibians of the southeastern United States: The status of southeastern amphibians, Alabama, Florida, Georgia, South Carolina (with minor notes on adjoining areas). A report to the Task Force on Declining Amphibians Populations. National Biological Survey, Gainesville, Florida.
- Enge, K. M., and W. Marion. 1986. Effects of clearcutting and site preparation on herpetofauna of a north Florida flatwoods. *Forest Ecology and Management* 14:177-192.
- Goin, C. J. 1950. A study of the salamander *Ambystoma cingulatum*, with the description of a new subspecies. *Annals of the Carnegie Museum* 31(14):299-321.
- Grant, B. W., K. L. Brown, G. W. Ferguson, and J. W. Gibbons. 1994. Changes in amphibian biodiversity associated with 25 years of pine forest regeneration: implications for biodiversity management. Pages 354-367 in S. K. Majumdar, F. J. Brenner, J. E. Lovich, J. F. Schalles, and E. W. Miller, editors. *Biological diversity: problems and challenges*. The Pennsylvania Academy of Science, Philadelphia.
- Hairston, N. G., Sr., and R. H. Wiley. 1993. No decline in salamander (*Amphibia: Caudata*) populations: a twenty-year study in the southern Appalachians. *Brimleyana* 18:59-64.
- Harte, J., and E. Hoffman. 1989. Possible effects of acidic deposition on a Rocky Mountain population of the tiger salamander, *Ambystoma tigrinum*. *Conservation Biology* 3:149-158.
- Herrington, R. E., and J. H. Larsen. 1985. Current status, habitat requirements and management of the Larch Mountain salamander *Plethodon larselli* (Burns). *Biological Conservation* 34:169-179.
- Jordan, R., Jr., and R. H. Mount. 1975. The status of the Red Hills salamander, *Phaeognathus hubrichti* Highton. *Journal of Herpetology* 9:211-215.
- Kautz, R. 1993. Trends in Florida wildlife habitat 1936-1987. *Florida Scientist* 1993:7-24.
- Martof, B. S. 1968. *Ambystoma cingulatum* (Cope). *Catalogue of American Amphibians and Reptiles* 57:1-57.2.

- Means, D. B. 1972. Notes on the autumn breeding biology of *Ambystoma cingulatum* (Cope) (Amphibia: Urodela: Ambystomidae). Page 84 in ASB Bulletin 19 Association of Southeastern Biologists, North Carolina.
- Means, D. B. 1986. Special concern: flatwoods salamander. Pages 42-43 in R. H. Mount, editor. Vertebrate animals of Alabama in need of special attention. Proceedings of the First Alabama Non-game Conference, 15-16 July 1983. Alabama Agricultural Experiment Station, Auburn University, Alabama.
- Means, D. B. 1996. Longleaf pine forest: going, going. . . In M. Davis, editor. Eastern old-growth forest: prospects for rediscovery and recovery. Island Press, Covelo, California.
- Mohr, C. 1987. The timber pines of the southern United States. Bulletin 13. U.S. Department of Agriculture, Division of Forestry, Washington, D.C.
- Neill, W. T. 1951. Notes on the roll of crawfishes in the ecology of reptiles, amphibians, and fishes. Ecology 32:764-766.
- Pechmann, J. H. K., D. E. Scott, R. D. Semlitsch, J. P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-895.
- Pentrack, J. W., M. E. Eldridge, and K. E. Haley. 1993. Effects of timber harvesting on southern Appalachian salamanders. Conservation Biology 7:363-370.
- Puri, H. S., and R. O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Special Publication 5. i-ix, 1-312, maps. Florida Geological Survey, Tallahassee.
- Raymond, L. R., and L. M. Hardy. 1991. Effects of a clearcut on a population of the mole salamander, *Ambystoma talpoideum*, in an adjacent unaltered forest. Journal of Herpetology 25:509-512.
- Schultz, R. P., and L. P. Wilhite. 1974. Changes in a flatwoods site following intensive population. Forest Science 20:230-237.
- Semlitsch, R. D. 1983. Structure and dynamics of two breeding populations of the eastern tiger salamander, *Ambystoma tigrinum*. Copeia 1983:608-616.
- Shoop, R. C. 1974. Yearly variation in the larval survey of *Ambystoma tigrinum*. Ecology 55:440-444.
- Smith, H. M. 1978. Amphibians of North America. Golden Press, New York.
- Travis, J. 1994. Calibrating our expectations in studying amphibian populations. Herpetologica 50:104-108.
- Tschinkel, W. 1993. The fire ant (*Solenopsis invicta*): still unvanquished. Pages 121-136 in B. N. McKnight, editor. Biological pollution: The control and impact of invasive exotic species. Indiana Academy of Science, Indianapolis.
- U.S. Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants: Animal candidate review for listing as endangered or threatened species. proposed rule. Federal Register 59 CFR Part 17, 59(217):58982-59028.
- U.S. Forest Service. 1984. Soils and vegetation of the Apalachicola National Forest. U.S. Forest Service, Tallahassee, Florida.
- Wahlenberg, W. G. 1946. Longleaf pine, its use, regeneration, protection, growth, and management. Charles Lathrop Pack Forestry Foundation, Washington, D.C.
- Wake, D. B. 1991. Declining amphibian populations. Science 253:860.
- Ware, S., C. Frost, and P. D. Doerr. 1993. Southern mixed hardwood forest: the former longleaf pine forest. Pages 447-493 in W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the southeastern United States. John Wiley & Sons, New York.
- Welsh, H. H., Jr. 1990. Relictual amphibians and old-growth forests. Conservation Biology 4:309-319.





Dated: November 25, 1997.

Director, Fish and Wildlife Service,

Samie Rappaport Clark,

[FR Doc. 97-32738 Filed 12-15-97; 8:45 am]

BILLING CODE 4310-55-P

## DEPARTMENT OF THE INTERIOR

### Fish and Wildlife Service

#### 50 CFR Part 17

RIN 1018-AE38

#### Endangered and Threatened Wildlife and Plants; Proposed Rule to List the Flatwoods Salamander as Threatened

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Proposed rule and notice of petition finding.

**SUMMARY:** The U.S. Fish and Wildlife Service (Service) proposes to list the flatwoods salamander (*Ambystoma cingulatum*) as a threatened species under the authority of the Endangered Species Act of 1973, as amended (Act). This salamander occurs in isolated populations scattered across the lower southeastern Coastal Plain in Florida, Georgia, and South Carolina. Habitat loss and degradation from agriculture, urbanization, and silvicultural practices have resulted in the loss of over 80 percent of its pine flatwoods habitat. Surviving populations are currently threatened by the continued destruction and degradation of their habitat. This proposed rule, if made final, would extend the Act's protection to this species.

**DATES:** Comments from all interested parties must be received by February 17, 1998. Public hearing requests must be received by January 30, 1998.

**ADDRESSES:** Comments and materials concerning this proposal should be sent to the Field Supervisor, U.S. Fish and Wildlife Service, 6578 Dogwood View Parkway, Jackson, Mississippi 39213. Comments and materials received will be available for public inspection, by appointment, during normal business hours at the above address.

**FOR FURTHER INFORMATION CONTACT:** Ms. Linda LaClaire at the above address, or telephone 601/965-4900, Ext. 26; facsimile 601/965-4340.

#### SUPPLEMENTARY INFORMATION:

##### Background

The earliest reference to the flatwoods salamander, *Ambystoma cingulatum*, was by Cope in 1867 from specimens he collected in Jasper County, South Carolina (referenced in Martof 1968).

This salamander is a member of the family Ambystomatidae, the mole salamanders, which contains 15 North American species. A phylogenetic analysis of ambystomatid salamanders was used to determine that the flatwoods salamander is most closely related to the ringed salamander (*A. annulatum*), which occurs in portions of Arkansas, Missouri, and Oklahoma (Shaffer *et al.* 1991).

The flatwoods salamander is a slender, small-headed mole salamander that rarely exceeds 13 centimeters (cm) (approximately 5 inches (in)) in length when fully mature (Means 1986, Conant and Collins 1991, Ashton 1992). Adult dorsal color ranges from black to chocolate-black with highly variable fine, light gray lines forming a netlike or cross-banded pattern across the back (Palis 1996). Undersurfaces are plain gray to black with a few creamy or pearl-gray blotches or spots. Sexual dimorphism is only apparent in breeding males (swollen cloacal region) or in gravid females. Adults most closely resemble Mabee's salamander, *A. mabeei*, with which it shares part of its range in South Carolina (Martof 1968). Mabee's salamanders are often more brownish; have light flecking concentrated on their sides rather than the overall pattern of the flatwoods salamander; and have a single row of jaw teeth as opposed to multiple rows in the flatwoods salamander (Conant and Collins 1991).

Flatwoods salamander larvae are long and slender, broad-headed and bushy-gilled, with white bellies and striped sides (Means 1986, Ashton 1992, Palis 1995d). They have distinctive color patterns, typically a tan mid-dorsal stripe followed by a grayish black dorsolateral stripe, a pale cream mid-lateral stripe, a blue-black lower lateral stripe and a pale yellow ventrolateral stripe (Palis 1995d). The head has a dark brown stripe passing through the eye from the nostril to the gills (Means 1986).

Optimum habitat for the flatwoods salamander is an open, mesic woodland of longleaf/slash pine (*Pinus palustris*/*P. elliotii*) flatwoods maintained by frequent fires. Pine flatwoods are typically flat, low-lying open woodlands that lie between the drier sandhill community upslope and wetlands down slope (Wolfe *et al.* 1988). An organic hardpan, 0.3 to 0.7 meters (m) (1 to 2 feet) into the soil profile, inhibits subsurface water penetration and results in moist soils with water often at or near the surface (Wolfe *et al.* 1988). Historically, longleaf pine generally dominated the flatwoods with slash pine restricted to the wetter areas (Wolfe

*et al.* 1988). Wiregrasses (*Aristida* sp.), especially *A. beyrichiana*, are often the dominant grasses in the herbaceous ground cover (Wolfe *et al.* 1988). The ground cover supports a rich herbivorous invertebrate community which serves as a food source for the flatwoods salamander.

Adult and subadult flatwoods salamanders are fossorial (adapted for living underground) (Mount 1975). They enlarge crayfish burrows (Ashton 1992) or build their own. Captive flatwoods salamanders have been observed digging burrows and resting at night with just the tip of their heads exposed (Goin 1950). Preliminary data indicate that flatwoods salamander males first breed at 1 year of age and females at 2 years of age (Palis 1996). There are no data on survivorship by age class for the species. The longevity record for their close relative, *A. annulatum*, is 4 years, 11 months; however, many Ambystomatidae live 10 years or longer (Snider and Bowler 1992).

Adult flatwoods salamanders move to their wetland breeding sites during rainy weather, in association with cold fronts, from October to December (Palis 1997). Breeding sites are isolated (not connected to any other water body) pond cypress (*Taxodium ascendens*), blackgum (*Nyssa sylvatica* var. *biflora*), or slash pine dominated depressions which dry completely on a cyclic basis. They are generally shallow and relatively small. Breeding sites in Florida have a mean size of 1.49 hectares (ha) (3.68 acres (ac)) and a mean depth of less than 39.2 cm (15.4 in) (Palis, in press). These wetlands have a marsh-like appearance with sedges often growing throughout and wiregrasses (*Aristida* sp.), panic grasses (*Panicum* spp.), and other herbaceous species concentrated in the shallow water edges. Trees and shrubs grow both in and around the ponds. A relatively open canopy is necessary to maintain the herbaceous component which serves as cover for flatwoods salamander larvae and their aquatic invertebrate prey. Flatwoods salamander larvae were not captured in sample plots with a high proportion of detritus or open water in a study on the Apalachicola National Forest in Florida (Sekerak *et al.*, in press). Ponds typically have a burrowing crayfish fauna (genus *Procambarus*) and a diverse macroinvertebrate fauna, but lack large predatory fish (e.g., *Lepomis* (sunfish), *Macropterus* (bass), *Ambloplites* (bowfin)).

Before the breeding sites become flooded, the males and females court and the females lay their eggs (singly or in clumps) beneath leaf litter, under logs

and sphagnum moss mats, or at bases of bushes, small trees, or clumps of grass (Anderson and Williamson 1976, Means 1986). Egg masses have also been found at the entrances of and within crayfish burrows (Anderson and Williamson 1976). Embryos begin development immediately, but the egg must be inundated before it will hatch. Depending on when eggs are inundated, the larvae usually metamorphose in March or April; the length of the larval period varies from 11 to 18 weeks (Palis 1995d).

The timing and frequency of rainfall is critical to the successful reproduction and recruitment of flatwoods salamanders. Fall rains are required to facilitate movements to the pond and winter rains are needed to ensure that ponds are filled sufficiently to allow hatching, development, and metamorphosis of larvae. In contrast, too much rainfall in the summer will keep pond levels from dropping below the grassy pond edge, as needed to provide dry substrate for egg deposition. This reliance on specific weather conditions results in unpredictable breeding events and reduces the likelihood that recruitment will occur every year.

Adult flatwoods salamanders leave the pond site after breeding. Studies have suggested a homing ability, based on data that salamanders exit the breeding pond near the point of their arrival (Palis 1997). Movements greater than 1,700 m (1,859 yards (yd)) from the breeding pond have been recorded (Ashton 1992). Preliminary studies indicate that the activity range of some individuals (encompassing both terrestrial habitat, breeding sites, and the areas through which they migrate) exceeds 1,500 square m (1,640 square yd) (Ashton 1992). Refugia are needed within this activity range as individuals travel from their breeding sites to the subterranean habitats where they spend the majority of their lives. Thus, a flatwoods salamander population has been defined as those salamanders using breeding sites within 3.2 kilometers (km) (2 miles (mi)) of each other, barring an impassable barrier such as a perennial stream (Palis, in press).

High quality habitat for the flatwoods salamander includes a number of isolated wetland breeding sites within a landscape of longleaf pine/slash pine flatwoods with an abundant herbaceous ground cover (Sekerak 1994). A mosaic of ponds with varying hydrologies is needed to provide appropriate breeding conditions under different climatic regimes.

The historical range of the flatwoods salamander included parts of the States

of Alabama, Florida, Georgia, and South Carolina located in the lower Coastal Plain of the southeastern United States. A museum record from Mississippi previously thought to be a flatwoods salamander has been discounted by knowledgeable researchers (Moler, pers. comm., 1988). However, it is possible that flatwoods salamanders once occurred in extreme southeastern Mississippi due to similarities in habitat to historical sites in adjacent Alabama. Recent surveys (Kuss 1988; L. LaClaire, U.S. Fish and Wildlife Service, pers. obs., 1995) have not documented the occurrence of flatwoods salamanders in Mississippi.

Historical records for the flatwoods salamander are limited. Longleaf pine/slash pine flatwoods historically occurred in a broad band across the lower southeastern Coastal Plain. The flatwoods salamander likely occurred in appropriate habitat throughout this area (Means, pers. comm., 1995). The present distribution of the flatwoods salamander consists of isolated populations scattered across the remaining longleaf pine/slash pine flatwoods. The Service has compiled 110 historical records for the flatwoods salamander. Historical records are defined as those localities found prior to 1990. Localities consist of collections made either by sampling breeding sites or collections made of individuals crossing highways on their way to or from breeding sites. During surveys of these localities over the last 7 years, the exact site was located for 52 records (47 percent) and the general area (within several miles) was determined for 45 others (41 percent). Thirteen sites could not be located due to limited information in the record. Of the 97 historical records that were visited, flatwoods salamanders were relocated at only 12 localities (12 percent).

Range-wide surveys of available habitat in Alabama, Florida, Georgia, and South Carolina have been ongoing since 1990 in an effort to locate new populations. A total of at least 1,189 wetlands, which had a minimum of marginal suitability for the flatwoods salamander, were sampled, most of them multiple times. Of these, flatwoods salamanders were found at 102 sites (9 percent success rate). Most surveys were presence/absence searches for larvae, thus no estimates of population size or viability can be inferred from these data.

Information on the current status of the flatwoods salamander by State can be briefly summarized as follows:

In Alabama, there are five historical localities for the flatwoods salamander, all in the extreme southern portion of the State. Surveys conducted from 1992

to 1995 at the historical breeding ponds and other potential breeding sites were not successful at locating any flatwoods salamander populations (Godwin 1994, pers. comm., 1997). The salamander was last observed in Alabama in 1981 (Jones et al. 1982).

A total of 33 historical records in 19 counties have been reported for Georgia (Goin 1950, Seyle 1994, Williamson and Moulis 1994); however, flatwoods salamanders have not been relocated at any of these sites in recent years. Surveys over the last 7 years of at least 451 wetlands with potential habitat for the flatwoods salamander have resulted in the location of 27 new breeding sites (6 percent success rate). These 27 breeding sites comprise 10 populations (sites within a 3.2 km (2 mi) radius of one another are considered the same population) (Seyle 1994; Jensen 1995; Moulis 1995a, 1995b; K. Lutz, The Nature Conservancy of Georgia, pers. comm., 1994; D. Stevenson, The Nature Conservancy of Georgia, pers. comm., 1996; L. LaClaire, pers. obs., 1995, 1997). Most extant breeding sites occur on Fort Stewart Military Installation.

In South Carolina, there are 29 historical records for the flatwoods salamander. Despite annual surveys since 1990, flatwoods salamanders have been found at only three of these sites (all sites represent a different population). One site is located on the Francis Marion National Forest and the other two are on private land. No new flatwoods salamander populations have been found, although surveys have been conducted at 57 additional wetlands considered to be potential habitat for this species.

In Florida, 39 of the 43 historical sites were relocated (or the general area thought to be the location). Nine (23 percent) contained flatwoods salamanders. Additional survey work over the past 7 years of at least 500 potential sites over a 22 county area resulted in the location of 75 new breeding sites (15 percent of total sites surveyed). The total number of extant flatwoods salamander populations known to occur in Florida is 34 with most occurring on the Apalachicola National Forest and Eglin Air Force Base (Palis 1993, 1994, 1995a, 1995b, 1995c; Printiss and Means 1996).

The combined State data from all survey work completed since 1990 indicate that 47 populations of flatwoods salamanders are known from across the historical range. Most of these occur in Florida (34 populations or 72 percent). Ten populations have been found in Georgia, three in South Carolina, and none have been found in Alabama. Some of these populations are



inferred from the capture of a single individual. Approximately half of the known populations for the flatwoods salamander occur on public land (25 of 47, or 53 percent). Federal landholdings that harbor flatwoods salamanders include the Apalachicola National Forest, Osceola National Forest, St. Marks National Wildlife Refuge, and Eglin Air Force Base in Florida; Fort Stewart Military Installation and Townsend Bombing Range in Georgia; and Francis Marion National Forest in South Carolina. An additional population is located on property managed by the State of Florida in the Pine Log State Forest. The remaining sites are on private land.

#### Previous Federal Action

The flatwoods salamander was identified as a Category 2 species in the Service's notices of review for animals published in the Federal Register on December 30, 1982 (47 FR 58454), September 18, 1985 (50 FR 37958), January 6, 1989 (54 FR 554), November 21, 1991 (56 FR 58804), and November 15, 1994 (59 FR 58982). Prior to 1996, a Category 2 species was one that was being considered for possible addition to the Federal List of Endangered and Threatened Wildlife, but for which conclusive data on biological vulnerability and threat were not currently available to support a proposed rule. Designation of Category 2 species was discontinued in the February 28, 1996, notice of review (61 FR 7956).

On May 18, 1992, the Service received a petition dated May 8, 1992, from the Biodiversity Legal Foundation, Boulder, Colorado, and Elizabeth Carlton, Gainesville, Florida, to list the flatwoods salamander as an endangered or threatened species throughout its historic range and to designate critical habitat. The petition stated that available evidence indicated that the flatwoods salamander had declined precipitously, that it was on the threshold of extirpation in many locations, and that it had been extirpated from a large portion of its historic range.

A 90-day finding that the petition did not present substantial information that the requested action may be warranted was announced in the Federal Register on May 12, 1993 (58 FR 27986). On August 23, 1993, attorneys representing the Biodiversity Legal Foundation, Jasper Carlton, the Director of the Biodiversity Legal Foundation, and Elizabeth Carlton notified the Service of their intent to sue the Service for violation of the Act. The petitioners felt a determination of "may be warranted"

had, in effect, already been made by the Service through the inclusion of the flatwoods salamander as a Category 2 species on the comprehensive notices of review for animals published prior to 1993. On April 25, 1994, the suit was filed. In response to the agreed settlement, and based upon the Service's 1994 draft guidance relating to petitions for listing former Category 2 species, the 90-day finding announced on May 12, 1993, was rescinded, and replaced by a finding that the petitioned action may be warranted. This finding was announced in the Federal Register on September 21, 1994 (59 FR 48406), and included a request for comments and biological data on the status of the flatwoods salamander.

Section 4(b)(3)(B) of the Act and implementing regulations at 50 CFR 424.14, require the Secretary of the Interior, to the extent practicable, within 12 months of receipt of a petition, to make a finding as to whether the action requested in the petition is (a) not warranted, (b) warranted, or (c) warranted but precluded. Because of budgetary constraints and the lasting effects of a congressionally imposed listing moratorium, the Service is processing petitions and other listing actions according to the listing priority guidance published in the Federal Register on December 5, 1996 (61 FR 64475). In a Federal Register notice published on October 23, 1997 (62 FR 55628), the guidance was extended beyond fiscal year 1997 until such time as the fiscal year 1998 appropriations bill for the Department of the Interior becomes law and new final guidance is published. The fiscal year 1997 guidance clarifies the order in which the Service will process rulemakings following two related events: (1) the lifting on April 26, 1996, of the moratorium on final listings imposed on April 10, 1995 (Pub. L. 104-6), and (2) the restoration of significant funding for listing through passage of the Omnibus Budget Reconciliation Act passed on April 26, 1996, following severe funding constraints imposed by a number of continuing resolutions between November 1995 and April 1996. The guidance calls for giving highest priority to handling emergency situations (Tier 1) and second highest priority (Tier 2) to resolving the status of outstanding proposed listings. Third priority (Tier 3) is given to resolving the conservation status of candidate species and processing administrative findings on petitions to add species to the lists or reclassify threatened species to endangered status. The processing of this petition and proposed rule falls

under Tier 3. At this time, the Southeast Region has no pending Tier 1 actions and no overdue Tier 2 actions. Additionally, the guidance states that "effective April 1, 1997, the Service will concurrently undertake all of the activities presently included in Tiers 1, 2, and 3" (61 FR 64480). This proposed rule constitutes the Service's 12-month finding on the petitioned action.

#### Summary of Factors Affecting the Species

Section 4(a) of the Endangered Species Act and regulations (50 CFR part 424) promulgated to implement the listing provisions of the Act set forth the procedures for adding species to the Federal lists. A species may be determined to be an endangered or threatened species due to one or more of the five factors described in section 4(a)(1). These factors and their application to the flatwoods salamander (*Ambystoma cingulatum* Cope) are as follows:

A. *The present or threatened destruction, modification, or curtailment of its habitat or range.* The major threat to the flatwoods salamander is loss of both its longleaf pine/slash pine flatwoods terrestrial habitat and its isolated, seasonally ponded breeding habitat. The combined pine flatwoods (longleaf pine-wiregrass flatwoods and slash pine flatwoods) historical acreage was approximately 12.8 million ha (32 million ac) (Wolfe et al. 1988, Outcalt 1997). Today, the combined flatwoods acreage has been reduced to 2.3 million ha (5.6 million ac) or approximately 18 percent of its original extent. These remaining pine flatwoods (non-plantation forests) areas are typically fragmented, degraded, second-growth forests.

Large acreages of pine flatwoods have been eliminated through land use conversions, primarily urban development and conversion to agriculture and pine plantations (Schultz 1983, Stout and Marion 1993, Outcalt and Sheffield 1996, Outcalt 1997). Surveys of historical flatwoods salamander localities documented the destruction of nine sites from urban development or agriculture and loss of three additional sites due to their conversion to pine plantations. State forest inventories completed between 1989 and 1995 indicate that flatwoods losses through land use conversion are still occurring (Outcalt 1997). In Florida and Georgia, the State's pine flatwoods habitat is concentrated and where most flatwoods salamander populations occur, 52,600 ha (130,000 ac) were lost to urban and agricultural use during the survey cycle of 8 years (Outcalt 1997).

Conversion of existing pine flatwoods second-growth forests to managed plantations is also continuing. In Georgia and Florida, there was a yearly loss of this habitat to pine plantations of nearly 20,200 ha (50,000 ac) in each State with a loss of 24 percent and 20 percent respectively during the 8 year survey interval (Outcalt 1997). Most of the remaining second-growth pine flatwoods (56 percent) occur on private non-industrial lands which are continuing to be converted to pine plantations after harvest (Outcalt 1997). Urban development is expanding into forested areas, especially in rapidly developing areas of Florida and Georgia. If present rates of loss continue, in 25 years nearly all natural pine flatwoods stands could be destroyed in these two States (Outcalt 1997).

Flatwoods salamander wetland breeding sites have also been degraded and destroyed. The number and diversity of these small wetlands have been reduced by alterations in hydrology, agricultural and urban development, silvicultural practices (described in more detail below), dumping in or filling of ponds, conversion of wetlands to fish ponds, domestic animal grazing, and soil disturbance (Vickers *et al.* 1985, Ashton 1992). Hydrological alterations represent the primary threat to flatwoods salamander breeding sites. Size and suitability of wetlands as breeding sites depend on subsoil moisture, the permeability of the hardpan, the pond's drainage area, and other factors. Alterations to any of these factors can affect the pond's ability to hold water and function as a breeding site.

Forest management strategies commonly used on pine plantations contribute to degradation of flatwoods salamander forested and wetland habitat. These include soil-disturbing site preparation techniques, lowered fire frequencies and reductions in average area burned per fire event (see Factor E), high seedling stocking rates, and herbicide use which reduces plant diversity in the understory. The result of these strategies is a forest that approaches even-age structure, has a dense understory, and low herbaceous cover. Forestry practices that directly affect wetland breeding sites include ditching ponds or low areas to drain water from a site, converting second-growth pine forests to bedded pine plantations, harvesting cypress from the ponds, disposing of slash in wetlands during timber operations, using ponds as part of ditched fire breaks, using fertilizers near wetlands which can result in eutrophication, and disturbing

the soil at a wetland (Vickers *et al.* 1985; Ashton 1992; Means *et al.* 1996; Palis, in press).

Clear-cut harvesting of forested sites appears to be an additional threat. Studies on this type of harvest have demonstrated negative short-term impacts on local amphibian populations, especially salamanders (deMaynadier and Hunter 1995). Raymond and Hardy (1991) monitored the mole salamander (*A. talpoideum*) at a breeding site adjacent to a recent clear-cut. They found that salamanders were displaced from the cut side of the pond and that there was lowered survivorship in individuals of the breeding population that immigrated to the breeding pond from the clear-cut. Flatwoods salamanders may be vulnerable to the microhabitat drying from clear-cuts due to their moist permeable skin which acts as a respiratory organ and must remain moist to function properly (Duellman and Trueb 1986).

Silvicultural practices affecting both upland and breeding habitats have been implicated in the decline of a flatwoods salamander population located in the panhandle of western Florida and monitored for over 20 years (Means *et al.* 1996). The observed decline at this site was attributed to habitat modifications resulting from clear-cutting, conversion of the site to a pine plantation, and fire suppression. Habitat modifications included soil disturbance, hydrologic changes, canopy closure, and loss of herbaceous ground cover.

Habitat quality data were collected during recent surveys of historical sites where flatwoods salamanders were not relocated. Habitat quality at these sites was characterized as none (site destroyed), low (flatwoods salamanders unlikely), moderate (salamanders possible but habitat degraded), or high (habitat appears suitable for flatwoods salamanders). Three historical flatwoods salamander localities (assigned a quality of none) were altered so greatly by their conversion to slash pine plantations that they were no longer even marginally suitable for the flatwoods salamander. Forty-one historical sites (41 of 97, or 42 percent) were of low or moderate habitat quality. Most of these sites had been converted to slash pine plantations and had a subsequent loss of habitat suitability (L. LaClaire, pers. obs., 1997).

The habitat quality surrounding historical flatwoods salamander breeding ponds in Florida, where flatwoods salamanders have been found in recent surveys, was characterized by Palis (in press). Each site was assigned a score based on pine species dominance and disturbance (second-

growth flatwoods versus plantation sites) and the relative abundance of wiregrass (*Aristida* sp.) ground cover. Wiregrass was chosen as a factor of habitat quality because its loss has been used as an indicator of site degradation from fire suppression and/or soil disturbance (Clewett 1989). In Palis' study, approximately 70 percent of the active breeding sites were surrounded by second-growth longleaf or slash pine flatwoods with nearly undisturbed wiregrass ground cover. In general, Palis found that the extant populations of the flatwoods salamander principally occurred on forest lands managed for long rotation, saw-timber production, rather than on short rotation pine plantations managed for pulp production.

Road construction plays a part in habitat degradation and destruction. At least one historical flatwoods breeding site was filled in association with the construction of a road (Palis 1993). Roads increase the accessibility of breeding ponds to off-road vehicle enthusiasts that use pond basins for "mud bogging" which disturbs the soil and vegetation and degrades the quality of a site for flatwoods salamander breeding. Roads may also alter the quality of isolated wetlands by draining, damming, or redirecting the water in a basin and contributing hydrocarbons and other chemical pollution via runoff and sedimentation.

A number of habitat degradation factors are implicated in the decline of one South Carolina flatwoods salamander population monitored for over 20 years (Moulis 1987, Bennett pers. comm. 1997). This site is bisected by a road that flatwoods salamanders have to cross to reach their breeding site. Much of the upland area, in which the salamanders dwell as adults, has undergone urban development (Bennett pers. comm. 1997). In addition, fire suppression has resulted in the loss of the open, grassy edge associated with quality breeding sites. Habitat quality at this site has degraded to the point where successful reproduction and recruitment are infrequent and the population is at risk.

Extensive surveys have been conducted over the past 7 years in Alabama, Georgia, Florida, South Carolina and Mississippi to search for flatwoods salamanders at historical localities and at other potential sites. The low level of success of these surveys is believed to be a reflection of both the loss of upland and isolated wetland breeding habitat and the reduction in the quality of these habitats.

B. *Overutilization for commercial, recreational, scientific, or educational purposes.* Overcollecting for scientific purposes may have contributed to the decline of a South Carolina population which was also impacted by habitat degradation. Between 1970 and 1976, a minimum of 84 adults and 870 larvae were collected in this area. Only two flatwoods salamanders have been captured at this locality since 1990, in spite of annual monitoring.

Overcollecting does not presently appear to be a significant threat to populations; however, it may become a problem if the specific locations become available to the general public. The rarity, uniqueness, and attractiveness of the species make the flatwoods salamander a candidate for the pet trade, should it become easy to obtain.

At some sites, larval flatwoods salamanders have been killed in association with bait harvesting for crayfish (Palis 1996). However, while this practice has caused the loss of some individuals, it is not currently thought to be a significant threat to the species as a whole.

C. *Disease or predation.* Disease is currently unknown in the flatwoods salamander.

Exposure to increased predation from fish is a potential threat to the flatwoods salamander when isolated, seasonally ponded breeding sites are changed to more permanent wetlands and become inhabited by fish. Ponds may be modified specifically to serve as fish ponds or sites may be altered due to the construction of drainage ditches or firebreaks which provide avenues for fish to enter the wetlands. Studies of other ambystomatid species have demonstrated a decline in larval survival in the presence of predatory fish (Semlitsch 1987, 1988).

D. *The inadequacy of existing regulatory mechanisms.* Regulatory mechanisms currently in effect do not provide adequate protection for the flatwoods salamander and its habitat. There are no existing regulatory mechanisms for the protection of the upland habitats where flatwoods salamanders spend most of their lives. Section 404 of the Clean Water Act is the primary Federal law that has the potential to provide some protection for the wetland breeding sites of the flatwoods salamander. Under section 404, nationwide permit 26 allows these wetlands to be filled with no review process if wetlands are less than 0.13 ha ( $\frac{1}{3}$  ac) and with only minimal review if they are between 0.13 ha and 1.2 ha (3 ac) in size. Nationwide permit 26 cannot be used if there is a potential negative effect on a listed species.

Some populations on Federal lands have benefitted where prescribed burning has been used as a regular management tool. However, multiple use priorities on public lands, such as timber production, and military and recreational use, make protection of the flatwoods salamander secondary. The National Environmental Policy Act (NEPA) requires an intensive environmental review of projects that may adversely affect a federally listed species, but project proponents are not required to avoid impacts to non-listed species.

At the State and local levels, regulatory mechanisms are also limited. The flatwoods salamander is listed as a rare protected species in the State of Georgia (Seyle 1994). This designation protects the species by prohibiting actions that cause direct mortality or the destruction of its habitat on lands owned by the State of Georgia and by preventing its sale, purchase, or possession (Jensen, pers. comm., 1997). At present, there are no known flatwoods salamander populations on lands owned by the State of Georgia. In South Carolina, the flatwoods salamander is listed as endangered (Bennett 1995). Prohibitions extend only to the direct take of the flatwoods salamander (Bennett, pers. comm., 1997). These regulations offer no protection against the most significant threat to the flatwoods salamander, which is loss of its habitat. The flatwoods salamander is considered rare in Florida by the Florida Committee on Rare and Endangered Plants and Animals (Ashton 1992); however, there are no protective regulations for this species or its habitat in the State (Moler 1990).

E. *Other natural or manmade factors affecting its continued existence.* Fire is needed to maintain the natural pine flatwoods community. Fire suppression has been considered the primary reason for the degradation of remaining longleaf pine forest acreage (Means 1996b). Wolfe *et al.* (1988) reported that pine flatwoods naturally burn every 3 to 4 years, probably most commonly in the summer months. Sampling of longleaf pine flatwoods sites in Florida indicated that less than 30 percent of sites on private lands were being prescribed burned to mimic the effects of natural fire (Outcalt 1997). The disruption of the natural fire cycle has resulted in an increase in slash pine on sites formerly dominated by longleaf pine, an increase in hardwood understorey, and a decrease in herbaceous ground cover (Wolfe *et al.* 1988; Means, pers. comm., 1995). Ponds surrounded by pine plantations and protected from the natural fire regime

become unsuitable flatwoods salamander breeding sites due to canopy closure and the resultant reduction in emergent herbaceous vegetation needed for egg deposition and larval development sites (Palis 1993). Of the 13 historical flatwoods salamander localities altered to the point where the habitat was no longer suitable, fire suppression was a contributing factor in at least 5 (38 percent). Current forest management is moving away from burning as a management tool due to liability considerations and concerns that fire will damage the quality of the timber. When burning is used as a management tool, winter fires are commonly employed. Winter fires may not be optimal for the flatwoods salamander.

Habitat fragmentation of the longleaf pine ecosystem, resulting from habitat conversion, threatens the survival of the remaining flatwoods salamander populations. Forty-seven populations occur across four States. Fifty-three percent (25 of 47) of these populations are widely separated from each other by unsuitable habitat. Research conducted in Florida documented that 25 percent of remaining longleaf pine flatwoods sites were isolated fragments imbedded in agricultural and urban-dominated landscapes (Outcalt 1997). Studies have shown that the loss of fragmented populations is common, and recolonization is critical for their regional survival (Fahrig and Merriam 1994, Burke 1995). As patches of available habitat become separated beyond the dispersal range of a species, populations are more sensitive to genetic, demographic, and environmental variability and may be unable to recover (Gilpin 1987, Sjogren 1991). Amphibian populations may be unable to recolonize areas after local extinctions due to their physiological constraints, relatively low mobility, and site fidelity (Blaustein *et al.* 1994).

Roads contribute to habitat fragmentation by isolating blocks of remaining contiguous habitat. Migration routes and dispersal of individuals to and from breeding sites may be disrupted. In addition, flatwoods salamanders may be killed by vehicles when attempting to cross roads (Means 1996a).

Pesticides and herbicides may pose a threat to amphibians such as the flatwoods salamander, because their permeable eggs and skin readily absorb substances from the surrounding aquatic or terrestrial environment (Duellman and Trueb 1986). They may be exposed to pesticides and herbicides accumulated in their invertebrate prey or their prey may be reduced through



the use of pesticides. In frogs, use of agricultural pesticides has resulted in lower survival rates, deformities, and lethal effects on tadpoles (Sanders 1970, FROGLOG 1993). Other negative effects of commonly used pesticides and herbicides on amphibians include delayed metamorphosis, paralysis, reduced growth rates, and mortality (Bishop 1992). Herbicides also alter the density and species composition of vegetation surrounding a breeding site and may reduce the number of potential sites for egg deposition, larval development, or shelter for migrating salamanders.

Long-lasting droughts or frequent floods may affect local flatwoods salamander populations. Although these are natural processes, other threats such as habitat fragmentation and habitat degradation may stress a population to the point that it cannot recover or recolonize other sites.

The Service has carefully assessed the best scientific and commercial information available regarding the past, present, and future threats faced by this species in determining to propose this rule. Based on this evaluation, the preferred action is to list the flatwoods salamander as threatened. The range and habitat of this species has been significantly reduced by activities associated with conversion of forests to agriculture and urban development, silvicultural practices, and the disruption of natural fire cycles. Remaining populations are vulnerable as suitable habitat continues to be lost or degraded by these activities. While not in immediate danger of extinction, the flatwoods salamander is likely to become an endangered species in the foreseeable future if the present trend continues.

#### Critical Habitat

Critical habitat is defined in section 3 of the Act as: (i) The specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) that may require special management consideration or protection and; (ii) specific areas outside the geographical area occupied by a species at the time it is listed, upon a determination that such areas are essential for the conservation of the species. "Conservation" means the use of all methods and procedures needed to bring the species to the point at which listing under the Act is no longer necessary.

Section 4(a)(3) of the Act, as amended, and implementing regulations

(50 CFR 424.12) require that, to the maximum extent prudent and determinable, the Secretary designate critical habitat at the time the species is determined to be endangered or threatened. Service regulations (50 CFR 424.12(a)(1)) state that designation of critical habitat is not prudent when one or both of the following situations exist: (1) The species is threatened by taking or other activity and the identification of critical habitat can be expected to increase the degree of threat to the species or (2) such designation of critical habitat would not be beneficial to the species. The Service finds that designation of critical habitat is not prudent for the flatwoods salamander.

Critical habitat designation, by definition, directly affects only Federal agency actions. Activities that might affect the flatwoods salamander on Federal lands include forestry management, military activities, and Federal actions that would impact the hydrology of the wetlands used by the flatwoods salamander for reproduction. Such activities would be subject to review under section 7(a)(2) of the Act, whether or not critical habitat was designated. Federal permit issuance on private lands would also be subject to review; however, the primary activities affecting habitat for the flatwoods salamander on private lands are silvicultural, and are not subject to the Federal review process under section 7.

Section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species or to destroy or adversely modify its critical habitat. Common to definitions of the "jeopardy" and "adverse modification" standards is an appreciable detrimental effect on both survival and recovery of the species. The Service currently believes that any significant adverse modification or destruction of flatwoods salamander habitat to the extent that survival and recovery is appreciably diminished would likely jeopardize this species' continued existence. Therefore, habitat protection from Federal actions can be accomplished for the flatwoods salamander through the section 7 jeopardy standard. The Service is currently working with the appropriate Federal land managing agencies to identify, protect, and manage flatwoods salamander habitat.

On private lands, industrial timber landowners are cooperating with the Service to conduct surveys for the flatwoods salamander and to develop management strategies to protect its habitat. Should this rule become final, the Service will continue to coordinate

with State and Federal agencies, as well as private property owners and other affected parties through the recovery process to manage habitat for the flatwoods salamander.

The Service believes that any potential benefits to critical habitat designation are outweighed by additional threats to the species that would result from such designation. Collecting for scientific and recreational purposes is a potential threat to the survival of the flatwoods salamander (see Factor B). Flatwoods salamanders are a rare and attractive species, and these characteristics make them potentially valuable in the pet trade. The collection of amphibians and reptiles for the pet trade has increased in recent years. For example, all box turtles have been placed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora due to the increased commercialization of these species. Collection of amphibians and reptiles for personal use and the pet trade is common in the vicinity of the most viable flatwoods salamander populations (K. Enge, Florida Game and Fresh Water Fish Commission, pers. comm., 1997). Permits are required for commercial collecting; however, collection regulations are difficult to monitor and enforce. Flatwoods salamanders concentrate for breeding and reproduction around breeding ponds, where they are most vulnerable to collecting. Publication of specific localities of breeding ponds would be required in the critical habitat designation process in order to obtain the notification benefit provided by such designation. The publication of breeding pond sites would increase the flatwoods salamander's level of vulnerability to illegal collecting.

Based on the above analysis, the Service has concluded that critical habitat designation would provide little additional benefit for the flatwoods salamander beyond that which would result from listing under the Act. The Service also concludes that any potential benefit from such a designation would be offset by an increased level of vulnerability to collecting.

#### Available Conservation Measures

Conservation measures provided to species listed as endangered or threatened under the Act include recognition, recovery actions, requirements for Federal protection, and prohibitions against certain activities. Recognition through listing results in public awareness and conservation actions by Federal, State, and local

agencies, private organizations, and individuals. The Act provides for possible land acquisition and cooperation with the States and requires that recovery actions be carried out for all listed species. The protection required of Federal agencies and the prohibitions against taking and harm are discussed, in part, below.

Section 7(a) of the Act, as amended, requires Federal agencies to evaluate their actions with respect to any species that is listed as endangered or threatened and with respect to its critical habitat, if any is designated. Regulations implementing this interagency cooperation provision of the Act are codified at 50 CFR part 402. Section 7(a)(4) requires Federal agencies to confer informally with the Service on any action that is likely to jeopardize the continued existence of a proposed species or result in destruction or adverse modification of proposed critical habitat. If a species is subsequently listed, section 7(a)(2) requires Federal agencies to ensure that activities they authorize, fund, or carry out are not likely to jeopardize the continued existence of the species or destroy or adversely modify its critical habitat. If a Federal action may affect a listed species or its critical habitat, the responsible Federal agency must enter into formal consultation with the Service.

The flatwoods salamander occurs on Federal lands administered by the Department of Defense, Fish and Wildlife Service, and U.S. Forest Service. These land management agencies would be required to evaluate the potential adverse impacts to the flatwoods salamander from their activities. Federal activities that could impact the flatwoods salamander through destruction or modification of suitable habitat include, but are not limited to, forest management, military operations, and road construction. Other Federal agencies that may be involved in authorizing, funding, or permitting activities that may affect the flatwoods salamander include the Army Corps of Engineers, due to their review of dredge and fill of isolated wetlands under section 404 of the Clean Water Act, nationwide permit 26; the Federal Energy Regulatory Commission, due to their oversight of gas pipeline and power line rights-of-way; and the Federal Highway Administration when Federal funds are involved in road construction. It has been the experience of the Service, however, that nearly all section 7 consultations have been resolved so that the species have been protected and the project objectives have been met.

The Act and its implementing regulations set forth a series of general prohibitions and exceptions that apply to all threatened wildlife. The prohibitions, codified at 50 CFR 17.21 and 17.31 for threatened wildlife, in part, make it illegal for any person subject to the jurisdiction of the United States to take (includes harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect; or to attempt any of these), import, export, ship in interstate commerce in the course of commercial activity, or sell or offer for sale in interstate or foreign commerce any listed species. It is also illegal to possess, sell, deliver, carry, transport, or ship any such wildlife that has been taken illegally. Certain exceptions apply to agents of the Service and State conservation agencies.

Permits may be issued to carry out otherwise prohibited activities involving threatened wildlife species under certain circumstances. Regulations governing permits are codified at 50 CFR 17.32 for threatened species. Such permits are available for scientific purposes, to enhance the propagation or survival of the species, and/or for incidental take in connection with otherwise lawful activities. For threatened species, permits also are available for zoological exhibition, educational purposes, or special purposes consistent with the purposes of the Act. In some instances, permits may be issued for a specified time to relieve undue economic hardship that would be suffered if such relief were not available. However, since this species is not currently in trade, such permit requests are not expected.

It is the policy of the Service, published in the Federal Register on July 1, 1994 (59 FR 34272), to identify, to the maximum extent practicable, those activities that would or would not constitute a violation of section 9 of the Act if the species is listed. The intent of this policy is to increase public awareness of the effects of the proposed listing on future and ongoing activities within a species' range. Activities which the Service believes are unlikely to result in a violation of section 9 for the flatwoods salamander are:

- (1) Possession of legally acquired flatwoods salamanders;
- (2) Lawful hunting activities;
- (3) Lawful burning of habitat where the flatwoods salamander is known to occur, when used as a forest or wildlife management technique, including winter burning;
- (4) Federally approved projects that involve activities such as discharge of fill material, draining, ditching, tiling, bedding, diversion or alteration of

surface or ground water flow into or out of a wetland (i.e., due to roads, impoundments, discharge pipes, etc.), when such activity is conducted in accordance with any reasonable and prudent measures given by the Service in accordance with section 7 of the Act;

(5) Conversion of pine flatwoods habitat where the flatwoods salamander does not occur;

(6) Timber harvesting (including clear-cutting) in pine flatwoods habitat where the flatwoods salamander does not occur; and

(7) Crayfish bait collecting operations that do not harm flatwoods salamanders.

Activities that the Service believes would be likely to result in a violation of section 9, if the species is listed, include, but are not limited to:

(1) Unauthorized collecting or handling of individual flatwoods salamanders;

(2) Possessing, selling, transporting, or shipping illegally taken flatwoods salamanders;

(3) Unauthorized destruction or alteration of wetlands used as breeding sites by flatwoods salamanders. These actions would include discharge of fill material, draining, ditching, tiling, bedding, diversion or alteration of surface or ground water flow into or out of a wetland (i.e., due to roads, impoundments, discharge pipes, etc.), and operation of any vehicles within the wetland;

(4) Discharge or dumping of toxic chemicals, silt, or other pollutants (i.e., sewage, oil, and gasoline) into isolated wetlands or upland habitats supporting the species; and

(5) Unlawful destruction or alteration of suitable pine flatwoods habitat within a 1.6-km (1-mi) radius surrounding a known flatwoods salamander breeding pond. These actions would include, but are not limited to, destruction of the herbaceous ground cover or alteration of a site's existing hydrology, such as might result from conversion of habitat to agricultural or urban use, conversion of habitat to intensively managed pine plantations, or ditching and draining a site.

Other activities not identified above will be reviewed on a case-by-case basis to determine whether a violation of section 9 of the Act may be likely to result from such activities should the flatwoods salamander become listed. The Service does not consider these lists to be exhaustive and provides them as information to the public.

Questions regarding whether specific activities may constitute a future violation of section 9, should this species be listed, should be directed to

the Field Supervisor of the Service's Jackson Field Office (see ADDRESSES section). Requests for copies of the regulations regarding listed wildlife and inquiries about prohibitions and permits may be addressed to the U.S. Fish and Wildlife Service, 1875 Century Blvd., Suite 200, Atlanta, Georgia 30345, or telephone 404/679-7319; facsimile 404/679-7081.

Section 10(a)(1)(B) authorizes the Service to issue permits for the taking of listed species incidental to otherwise lawful activities such as agriculture, forestry, and urban development. Take permits authorized under section 10 must be supported by a habitat conservation plan (HCP) that identifies conservation measures that the permittee agrees to implement to conserve the species. A key element of the Service's review of a HCP is a determination of the plan's effect upon the long-term conservation of the species. The Service would approve a HCP, and issue a section 10(a)(1)(B) permit if the plan would minimize and mitigate the impacts of the taking and would not appreciably reduce the likelihood of the survival and recovery of that species in the wild.

#### Public Comments Solicited

The Service intends that any final action resulting from this proposal will be as accurate and as effective as possible. Therefore, comments or suggestions from the public, other concerned governmental agencies, the scientific community, industry, or any other interested party concerning this proposed rule are hereby solicited. Comments are particularly sought concerning:

(1) Biological, commercial trade, or relevant data concerning any threat (or

lack thereof) to the flatwoods salamander;

(2) The location of any additional populations of this species and the reasons why any habitat should or should not be determined to be critical habitat as provided by section 4 of the Act;

(3) Additional information concerning the range, distribution, and population size of this species; and

(4) Current or planned activities in the subject area and their possible impact on this species.

Final promulgation of the regulation on this species will take into consideration the comments and any additional information received by the Service, and such communications may lead to a final regulation that differs from this proposal.

The Act provides for one or more public hearings on the proposal, if requested. Requests must be received within 45 days of the date of publication of the proposal in the Federal Register. Such requests must be made in writing and addressed to the Field Supervisor (see ADDRESSES section).

#### National Environmental Policy Act

The Fish and Wildlife Service has determined that an Environmental Assessment, as defined under the authority of the National Environmental Policy Act of 1969, need not be prepared in connection with regulations adopted pursuant to section 4(a) of the Endangered Species Act of 1973, as amended. A notice outlining the Service's reasons for this determination was published in the Federal Register on October 25, 1983 (48 FR 49244).

#### Required Determinations

The Service has examined this regulation under the Paperwork Reduction Act of 1995 and found it to contain no information collection requirements.

#### References Cited

A complete list of all references cited herein, as well as others, is available upon request from the Field Supervisor, Jackson Field Office (see ADDRESSES section).

Author: The primary author of this proposed rule is Linda V. LaClaire, Jackson Field Office (see ADDRESSES section).

#### List of Subjects in 50 CFR Part 17

Endangered and threatened species, Exports, Imports, Reporting and record-keeping requirements, Transportation.

#### Proposed Regulation Promulgation

Accordingly, the Service hereby proposes to amend part 17, subchapter B of chapter I, title 50 of the Code of Federal Regulations, as set forth below:

#### PART 17—[AMENDED]

1. The authority citation for part 17 continues to read as follows:

Authority: 16 U.S.C. 1361-1407; 16 U.S.C. 1531-1544; 16 U.S.C. 4201-4245; Pub. L. 99-625, 100 Stat. 3500, unless otherwise noted.

2. Amend section 17.11(h) by adding the following, in alphabetical order under AMPHIBIANS, to the List of Endangered and Threatened Wildlife to read as follows:

#### § 17.11 Endangered and threatened wildlife.

\* \* \* \* \*

(h) \* \* \*

Species		Historic range	Vertebrate population where endangered or threatened	Status	When listed	Critical habitat	Special rules
Common name	Scientific name						
AMPHIBIANS							
Salamander flatwoods.	<i>Ambystoma cingulatum</i> .	U.S.A. (AL, FL, GA, SC).	Entire .....	T	NA	NA	

Dated: November 24, 1997.

Jamie Rappaport Clark,  
Director, Fish and Wildlife Service.

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BILLING CODE 4310-55-P



U.S. Fish and Wildlife Service  
6578 Dogwood View Parkway  
Jackson, MS 39213  
(601) 965-4900



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COMMONLY ASKED QUESTIONS AND ANSWERS  
ABOUT THE PROPOSED LISTING OF THE FLATWOODS SALAMANDER  
UNDER THE ENDANGERED SPECIES ACT

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1. WHAT IS THE ENDANGERED SPECIES ACT (ESA)? The ESA is a Federal law that recognizes and protects rare plants and animals that are endangered with extinction, or threatened with becoming endangered in the near future. Species are listed under the ESA based on the best available scientific evidence.
2. WHY IS THE FLATWOODS SALAMANDER BEING PROPOSED FOR LISTING? Survey efforts conducted since 1990 for flatwoods salamanders have located only about 50 scattered populations. Pine flatwoods habitat, upon which the salamander depends, has been reduced to less than 20% of its historical extent. That which remains continues to decline in amount and quality. After reviewing data on population status, habitat quantity and quality, and potential threats for the species, the U.S. Fish and Wildlife Service concluded that the flatwoods salamander qualified for threatened status under the Endangered Species Act.
3. WHERE DOES THE FLATWOODS SALAMANDER OCCUR? The flatwoods salamander is found in pine flatwoods across the lower coastal plain in Florida, Georgia, and South Carolina. Populations are distributed from the panhandle of Florida east to near Jacksonville, Florida; extreme southwest Georgia; and the coastal counties of Georgia and South Carolina from the Altamaha River north to the Francis Marion National Forest. About half of the known populations of flatwoods salamanders occur on public lands, including National Forests, wildlife refuges, and military bases. It is historically known from Alabama but it has not been observed in that State in over 15 years.
4. WHAT ARE PINE FLATWOODS AND DO ALL PINE FLATWOODS HAVE POTENTIAL HABITAT FOR THIS SPECIES? Pine flatwoods are open, moist, longleaf/slash pine forests that have a well-developed ground cover of grasses (typically wiregrass). This habitat type occurs along the lower coastal plain. Not all pine flatwoods are suitable for this species. The flatwoods salamander is only found in pine flatwoods that have the appropriate temporary ponds which the salamanders needs for breeding. These breeding ponds are isolated from other waterbodies, dry periodically, and usually have pond cypress, blackgum, or slash pine growing in or around them. These ponds are shallow and have a marsh-like appearance with sedges, grasses, and other herbaceous species in the shallow water edges.



5. HOW DO I KNOW IF FLATWOODS SALAMANDERS ARE ON MY LAND?

If you own pine flatwoods along the lower coastal plain in Alabama, Florida, Georgia, or South Carolina, and there are seasonal ponds on your land that fill with water during the winter and spring and become dry during the summer and fall, you may have flatwoods salamanders on your land. Breeding pond surveys for salamander larvae in the late winter and early spring are the easiest method for determining the presence of the flatwoods salamander. Your local U.S. Fish and Wildlife Service field office can help you determine if there is a potential for flatwoods salamander habitat on your property, and if so, provide information on appropriate survey techniques and qualified surveyors.

6. HOW WILL THE PRIVATE LANDOWNER BE AFFECTED BY THE LISTING OF THE FLATWOODS SALAMANDER?

Because of its' rarity, listing the flatwoods salamander as a threatened species will affect relatively few private landowners. Private lands within the range of the salamander that do not contain appropriate pine flatwoods habitat and breeding ponds, or lands which have appropriate habitat but no flatwoods salamanders, will not be affected by the potential listing.

If this species is listed, the basic responsibility of private landowners having flatwoods salamander populations on their lands would be to avoid "take" of the species. Take means to harass, harm, kill, trap, capture, or collect a species listed under the Act. This definition includes land use activities that may result in death or harm to the species. For example, draining or changing the hydrology of a breeding pond would limit the ability of a flatwoods salamander population to reproduce and would be a form of take. Direct destruction of the salamander's terrestrial habitats, by converting pine flatwoods surrounding breeding ponds from pine flatwoods to cultivation, pasture, or subdivisions, would also be likely to result in harm to, or death of flatwoods salamanders. Some silviculture activities may also result in take of salamanders. Heavy equipment may crush or entomb salamanders in their burrows. Extensive bedding can alter the hydrology so that the site becomes unsuitable. (Refer to question # 8 for information on minimizing negative effects associated with timber harvesting).

Habitat Conservation Plans, developed by private landowners working with the U.S. Fish and Wildlife Service, allows some individuals of a listed species to be "taken" under an "incidental take permit". Incidental take is take which occurs incidental to an otherwise lawful activity such as land conversion or timber harvest. The process requires some form of mitigation to address adverse effects on the species. Your local U.S. Fish and Wildlife Service office can review proposed activities to determine if take is likely to occur. If take is likely, the Service will work with private landowners to develop conservation plans that protect the flatwoods salamander and accommodate landowner's needs.

7. WILL ACTIVITIES SUCH AS FARMING, URBAN DEVELOPMENT, OR OTHER PRIVATE LAND USE BE RESTRICTED OR PROHIBITED IF THE FLATWOODS SALAMANDER IS LISTED?

Flatwoods salamanders are very limited in number and distribution, therefore, few activities are likely to be affected if it is listed as a threatened species. Flatwoods salamanders are NOT found in cultivated fields, pastures, or in urban settings, so such existing land uses would not be restricted. Recreational land use activities such as hunting and fishing would also not be affected. New development, dredging, filling, site conversion or other similar activities in areas identified as flatwoods salamander habitat should be coordinated with the U.S. Fish and Wildlife Service.

8. HOW WOULD THE LISTING OF THE FLATWOODS SALAMANDER IMPACT THE FOREST INDUSTRY? The Fish and Wildlife Service believes that timber management is the land use activity that has the greatest compatibility with the continued existence of this species. Timber management techniques that duplicate the natural ecological processes of the historical pine flatwoods ecosystem, such as burning and selective timber harvest, would provide the most benefit to flatwoods salamander populations. Silviculture management practices can be planned and conducted to reduce or possibly eliminate the potential for take of the flatwoods salamander. For example:

Thinning and tree harvest planned outside of the breeding and dispersal period (October to April);

Timber activities during dry periods, that do not compact or rut the soils or alter the native herbaceous ground cover or hydrology;

Natural regeneration of pine flatwoods forests, or using planting methods that do not require mechanical preparation (for example, not using techniques such as rollerchopping, disking, bedding, or rootraking);

Planning planting densities, thinnings, and growth to maintain an open understory and dense ground cover (60% maximum canopy closure);

Use of fire as a primary tool for site preparation and midstory and understory hardwood control; and

Use of herbicides and fertilizers during nonbreeding seasons and dry periods according to Best Management Practices and manufacturers recommendations. Direct application of herbicides (e.g. handspraying, injecting, etc.) is preferred. The Service recommends minimal use of herbicides and fertilizers in areas of flatwoods salamander breeding ponds and habitat until such time as research determines their effects on this species.

9. WHAT HAPPENS IF A LANDOWNER'S TIMBER MANAGEMENT ACTIONS ATTRACT OR INCREASE FLATWOODS SALAMANDERS ON THEIR LAND? Safe Harbor agreements can be developed which protect the landowner from increased liability under the Endangered Species Act due to positive activities that may benefit or attract listed species. If habitat improvements are such that populations of flatwoods salamanders become established or increase, they may be taken according to the terms of the Safe Harbor Agreement back to the original baseline established at the time of the agreement. Your local U.S. Fish and Wildlife Service field office can assist in determining if a Safe Harbor Agreement is appropriate, in the event that the flatwoods salamander becomes listed.

# Flatwoods salamander

## LITERATURE CITED

- Anderson, J. D. and G. K. Williamson. 1976. Terrestrial mode of reproduction in *Ambystoma cingulatum*. *Herpetologica* 32:214-221.
- Ashton, R. E., Jr. 1992. Flatwoods salamander (Cope). Pgs. 39-43 in: P. E. Moler (ed.). Rare and endangered biota of Florida: Volume III. Amphibians and reptiles, University Press of Florida, Gainesville, Florida.
- Bennett, S. H. 1995. Status survey for the flatwoods salamander (*Ambystoma cingulatum*) and the Carolina gopher frog (*Rana capito*) in South Carolina. Heritage Trust Program, South Carolina Department of Natural Resources, Columbia, South Carolina.
- Bishop, C. A. 1992. The effects of pesticides on amphibians and the implications for determining causes of declines in amphibian populations. Pgs. 67-70. in: C. A. Bishop and K. E. Pettit (eds.). Declines in Canadian amphibian populations: designing a national monitoring strategy. Occasional Paper Number 76, Canadian Wildlife Service, Ottawa, Ontario.
- Blaustein, A. R., D. B. Wake, and W. P. Sousa. 1994. Amphibian declines: judging stability, persistence, and susceptibility of populations to local and global extinctions. *Conservation Biology* 8:60-71.
- Burkey, T. V. 1995. Extinction rates in archipelagoes: implications for populations in fragmented habitats. *Conservation Biology* 9:527-541.
- Clewell, A. F. 1989. Natural history of wiregrass (*Aristida stricta* Michx., Gramineae). *Natural Areas Journal* 9:223-233.
- Conant, R. and J. T. Collins. 1991. A field guide to the reptiles and amphibians of Eastern and Central North America. Houghton Mifflin Co., Boston, Massachusetts. 450 pp.
- deMaynadier, P. G. and M. L. Hunter, Jr. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. *Environmental Reviews* 3:230-261.
- Duellman, W. E. and L. Trueb. 1986. Biology of amphibians. McGraw-Hill, New York, New York. 670 pp.
- Fahrig, L. and G. Merriam. 1994. Conservation of fragmented populations. *Conservation Biology* 8:50-59.

FROGLOG 1993. Summary of third conference on Declining Amphibian Populations, Canada. Newsletter of the World Conservation Union, Species Survival Commission Declining Amphibian Populations Task Force and Center of Analysis of Environmental Change, Corvallis, Oregon. Pg. 4

Gilpin, M. E. 1987. Spatial structure and population vulnerability. Pgs. 125-139. in: M. E. Soule (ed.). Viable populations for conservation. Cambridge University Press, Cambridge, United Kingdom.

Godwin, J. S. 1994. Status survey of the flatwoods salamander, *Ambystoma cingulatum*, in Alabama, 1992-93 and 1993-94. Report to Alabama Department of Conservation and Natural Resources, Montgomery, Alabama. 36 pp.

Goin, C. T. 1950. A study of the salamander *Ambystoma cingulatum*, with the description of a new subspecies. Annals of the Carnegie Museum 31:299-321.

Jensen, J. B. 1995. Survey of potential habitat on Okefenokee National Wildlife Refuge for *Ambystoma cingulatum*, *Rana capito*, and *Notophthalmus perstriatus*. Unpublished report to U.S. Fish and Wildlife Service, Jackson, Mississippi. 19 pp.

Jensen, J. B. and S. A. Johnson. 1998. Geographic distribution. *Ambystoma cingulatum* (Flatwoods salamander). Herpetological Review 29:244.

Jones, T. R., J. C. Godwin, and T. Lamb. 1982. *Ambystoma cingulatum*. Herpetological Review 13:51.

Kuss, B. D. 1988. A search for populations of the flatwoods salamander (*Ambystoma cingulatum*) in Mississippi. End of Year Report to Mississippi Museum of Natural Science, Jackson, Mississippi. 18 pp.

Martof, B. S. 1968. *Ambystoma cingulatum*. Catalogue of American Amphibians and Reptiles: 57.1-57.2.

Means, D. B. 1986. Special Concern: flatwoods salamander. Pgs. 42-43 in: R. H. Mount (ed). Vertebrate animals of Alabama in need of special attention. Alabama Agricultural Experiment Station, Auburn University, Auburn, Alabama.

Means, D. B. 1996a. A preliminary consideration of highway impacts on herpetofauna inhabiting small isolated wetlands in the southeastern U.S. coastal plain. Pgs. 1-11 in: G. L. Evink, P. Garrett, D. Zeigler, and J. Berry (eds.). Trends in addressing transportation related wildlife mortality. Proceedings of the transportation related wildlife mortality seminar. State of Florida, Department of Transportation, Tallahassee, Florida.

Means, D. B. 1996b. Longleaf pine forest, going, going,... Pgs. 210-229 in: M. B. Davis (ed.) Eastern Old-growth Forests. Island Press, Covelo, California.

- Means, D. B. 1998. Geographic distribution. *Ambystoma cingulatum* (Flatwoods salamander). Herpetological Review 29:47.
- Means, D. B., J. G. Palis, and M. Baggett. 1996. Effects of slash pine silviculture on a Florida population of the flatwoods salamander (*Ambystoma cingulatum*). Conservation Biology 10:426-437.
- Moler, P. E. 1990. A checklist of Florida's amphibians and reptiles. Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program, Tallahassee, Florida. 18 pp.
- Moulis, R. A. 1987. Survey of the distributional status in South Carolina of two amphibians of special concern: *Ambystoma cingulatum* (flatwoods salamander) and *Psuedobranchius striatus striatus* (broad-striped dwarf siren). Unpublished report submitted by Savannah Science Museum to South Carolina Wildlife and Marine Resources Department, Columbia, South Carolina. 8 pp.
- Moulis, R. A. 1995a. A survey of eastern Georgia for gopher frogs (*Rana capito* ssp.) with notes on the occurrence of *Notophthalmus perstriatus* and *Ambystoma cingulatum*. Unpublished report submitted to the U.S. Fish and Wildlife Service. 36 pp. + tables and figures.
- Moulis, R. A. 1995b. A survey of suitable habitat in southwestern Georgia for gopher frogs (*Rana capito* ssp.), striped newt (*Notophthalmus perstriatus*) and flatwoods salamander (*Ambystoma cingulatum*). Unpublished report submitted to the U.S. Fish and Wildlife Service. 11 pp. + tables and figures.
- Mount, R. H. 1975. The reptiles and amphibians of Alabama. Auburn University Agricultural Experiment Station, Auburn, Alabama. 347 pp.
- Outcalt K. W. 1997. Decline of the pine flatwoods of the southern Coastal Plain. Draft manuscript, USDA Forest Service, Athens, Georgia. 10 pp.
- Outcalt K. W. and R. M. Sheffield. 1996. The longleaf pine forest: trends and current conditions. USDA Forest Service, Southern Research Station, Asheville, North Carolina. 23 pp.
- Palis, J. G. 1993. A status survey of the flatwoods salamander, *Ambystoma cingulatum*, in Florida. Florida Natural Areas Inventory, Tallahassee, Florida. 29 pp. + appendices.
- Palis, J. G. 1994. Re-survey of 24 known breeding sites of the flatwoods salamander, *Ambystoma cingulatum*, on the Apalachicola National Forest, Florida. Unpublished report submitted to the U.S. Fish and Wildlife Service. 12 pp. + appendices.

- Palis, J. G. 1995a. A survey of flatwoods salamander (*Ambystoma cingulatum*) breeding sites east of the Apalachicola River, Florida. Unpublished report submitted to the U.S. Fish and Wildlife Service. 8 pp. + tables, figures, and appendices.
- Palis, J. G. 1995b. Geographic Distribution. *Ambystoma cingulatum* (Flatwoods Salamander). Herpetological Review 26:103.
- Palis, J. G. 1995c. Distribution and breeding biology of the flatwoods salamander (*Ambystoma cingulatum*) and gopher frog (*Rana capito*) on Eglin Air Force Base, Florida. Florida Natural Areas Inventory, Tallahassee, Florida. 32 pp. + appendices.
- Palis, J. G. 1995d. Larval growth, development, and metamorphosis of *Ambystoma cingulatum* on the Gulf Coastal Plain of Florida. Florida Scientist 58:352-358.
- Palis, J. G. 1996. Element stewardship abstract: Flatwoods salamander (*Ambystoma cingulatum*). Natural Areas Journal 16:49-54.
- Palis, J. G. 1997a. Breeding migration of *Ambystoma cingulatum* in Florida. Journal of Herpetology 31:71-78.
- Palis, J. G. 1997b. Distribution, habitat, and status of the flatwoods salamander (*Ambystoma cingulatum*) in Florida, USA. Herpetological Natural History 5:53-65.
- Printiss, D. J. and D. B. Means. 1996. Distribution of the flatwoods salamander, *Ambystoma cingulatum*, on the Osceola National Forest, Florida. Unpublished report submitted to the Osceola National Forest, Olustee, Florida. 5 pp. + appendices.
- Raymond, L. R. and L. M. Hardy. 1991. Effects of a clearcut on a population of the mole salamander, *Ambystoma talpoideum*, in an adjacent unaltered forest. Journal of Herpetology 25:509-512.
- Sanders, H. O. 1970. Pesticide toxicities to tadpoles of the western chorus frog, *Psuedacris triseriata*, and Fowler's toad, *Bufo woodhousii fowleri*. Copeia 2:246-251.
- Schultz, R. P. 1983. The original slash pine forest--An historical view. Pgs. 23-47 in: Proceedings of the managed slash pine ecosystem, University of Florida, Gainesville, Florida.
- Sekerak, C. M. 1994. Vegetation and aquatic vertebrate and macroinvertebrate assemblages in flatwoods salamander breeding ponds in the Apalachicola National Forest. Unpublished Master's thesis, University of Florida, Gainesville, Florida. 74 pp.
- Sekerak, C. M., G. W. Tanner, and J. G. Palis. 1996. Ecology of flatwoods salamander larvae in breeding ponds in Apalachicola National Forest. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50:321-330.

- Semlitsch, R. D. 1987. Interactions between fish and salamander larvae. *Oecologia* 72:481-486.
- Semlitsch, R. D. 1988. Allotopic distribution of two salamanders: effects of fish predation and competitive interactions. *Copeia* 1988:290-298.
- Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12:1113-1119.
- Seyle, W. 1994. Distribution and status of the gopher frog (*Rana capito*) and flatwoods salamander (*Ambystoma cingulatum*) in Georgia. Final report to U.S. Fish and Wildlife Service, Jackson, Mississippi. 18 pp. + tables and appendices.
- Shaffer, H. B., R. A. Alford, B. D. Woodward, S. J. Richards, R. G. Altig, and C. Gascon. 1994. Quantitative sampling of amphibian larvae. Pgs. 134-135 in: Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster (eds.). *Measuring and monitoring biological diversity. Standard methods for amphibians*. Smithsonian Institution Press, Washington, D.C.
- Shaffer, H. B., J. M. Clark, and F. Krause. 1991. When molecule and morphology clash: A phylogenetic analysis of the North American ambystomatid salamanders (Caudata: *Ambystoma*). *Systematic Zoology* 40:284-303.
- Snider, A. T. and J. K. Bowler. 1992. Longevity of reptiles and amphibians in North American collections. *Herpetological Circular* No. 21, Society for the Study of Amphibians and Reptiles, Lawrence, Kansas. 40 pp.
- Sjogren, P. 1991. Extinction and isolation gradients in metapopulations: the case of the pool frog (*Rana lessonae*). *Biological Journal of the Linnean society* 42:135-147.
- Southeastern Amphibian Survey Cooperative. 1998. Southeast Coastal Plain amphibian survey. Unpublished report to the U.S. Fish and Wildlife Service, Jackson, MS. 11 pp.
- Stout, I. J. and W. R. Marion. 1993. Pine flatwoods and xeric pine forests of the southern (lower) Coastal Plain. Pgs. 373-446. in: W. H. Martin, S. G. Boyce, A. C. and Echternacht (eds.). *Biodiversity of the southeastern United States. Lowland Terrestrial Communities*. John Wiley and Sons, Inc., New York, New York.
- Vickers, C. R., L. D. Harris, and B. F. Swindel. 1985. Changes in herpetofauna resulting from ditching of cypress ponds in coastal plains flatwoods. *Forest Ecology and Management* 11:17-29.
- Williamson, G. K. and R. A. Moulis. 1994. Distribution of amphibians and reptiles in Georgia. Volume 2-Locality data. Special Publication No. 3, Savannah Science Museum, Inc., Savannah, Georgia. 712 pp.



Wolfe, S. H., J. A. Reidenauer, and D. B. Means. 1988. An ecological  
characterization of the Florida Panhandle. U.S. Fish and Wildlife Service Biological Report  
88(12); Minerals Management Service, OCS StudyMMS 88-0063. 277 pp.

## BIOGEOGRAPHY AND STATUS OF THE STRIPED NEWT (*NOTOPHTHALMUS PERSTRIATUS*) IN GEORGIA, USA

C. Kenneth Dodd, Jr.

National Biological Service, 7920 NW. 71st Street, Gainesville, Florida, 32653, USA

Linda V. LaClaire

U. S. Fish and Wildlife Service, 6578 Dogwood View Parkway, Suite A, Jackson, Mississippi, 39213, USA

**Abstract.** A total of 108 ponds and wetlands throughout the Atlantic Coastal Plain of Georgia were sampled to determine the distribution of striped newts (*Notophthalmus perstriatus*). Sampling was concentrated at or near sites where striped newts had been reported historically. Several historical sites could not be located because of vague collection data; at least one pond has been destroyed. Striped newts presently are known from five, widely disjunct locations, including a pond near the type locality where the species was discovered in the 1920s. All sites are associated with well-drained, sandy uplands and terraces adjacent to rivers and large streams. Two routes of Pleistocene colonization are hypothesized, one following river terraces in the west and the other following marine and river terraces in the east. The extent of past and continuing habitat alteration suggests that the remaining populations are isolated. We recommend initiation of immediate efforts to monitor, conserve and manage known striped newt breeding ponds and adjacent uplands.

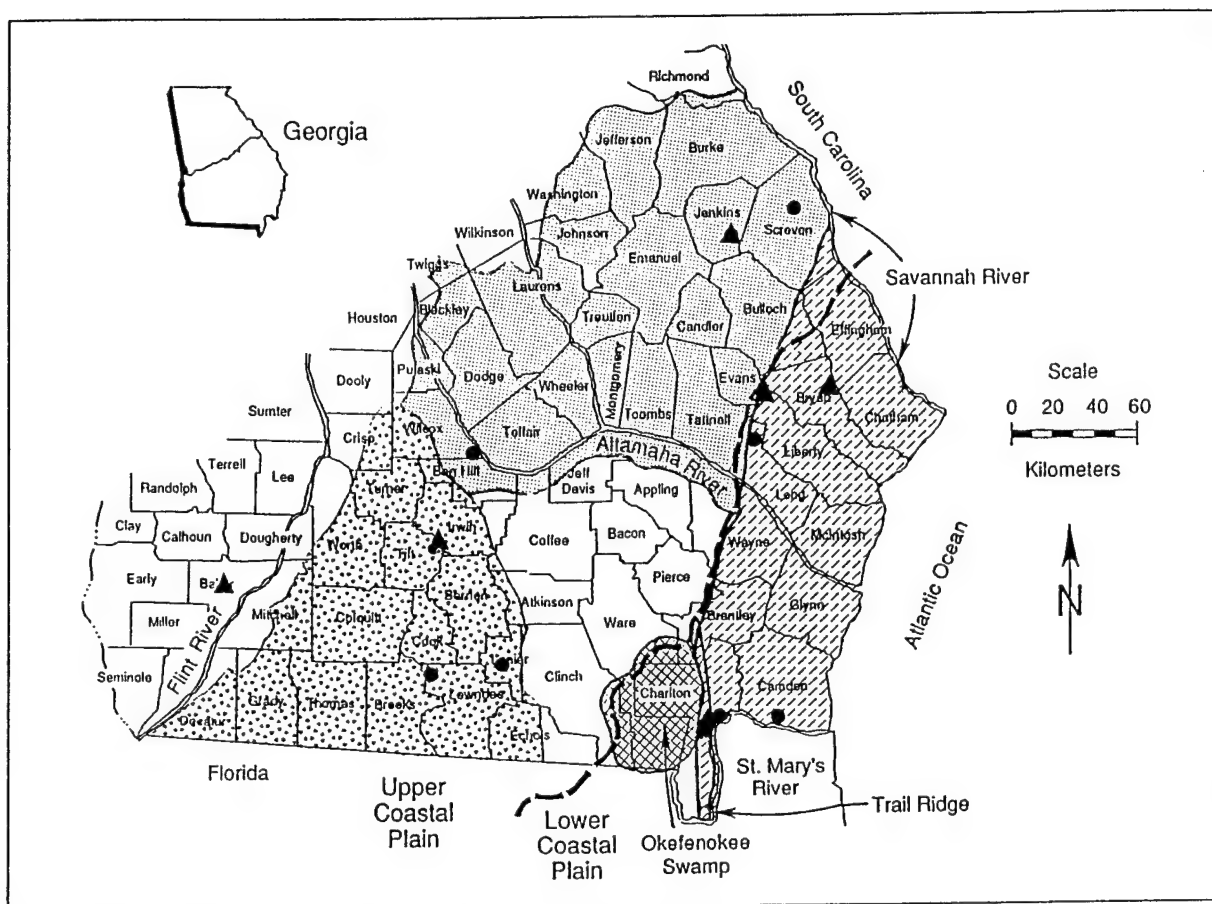
**Key Words.** Striped newt; *Notophthalmus perstriatus*; Biogeography; Distribution; Status; Georgia.

The striped newt (*Notophthalmus perstriatus*) is a poorly known species endemic to southern Georgia and north-central Florida. Biochemical evidence supports the uniqueness of this taxon and allies it with the xeric-adapted *N. meridionalis* of Texas and México (Reilly 1990). Adults breed only in temporary ponds, presumably from late winter to early spring, although Bishop (1941) noted the presence of adults in breeding condition in ponds as late as June. The larval period is unknown although larvae have been found from April through December in Florida (Christman and Means 1978). Other than food habits (Christman and Franz 1973) and miscellaneous reports on distribution and larvae (Ashton and Ashton 1985; Mecham 1967), few data are available on the species' biology. Information on population size-class structure and activity patterns are available only for a population at a temporary pond in sandhills of northern Florida (Dodd 1993). The striped newt is considered a rare species by the state of Georgia and a possible candidate for protection under U.S. federal law.

### HISTORICAL BACKGROUND

Prior to our survey, little was known concerning the distribution of *Notophthalmus perstriatus* in Georgia. Most records came from a region generally known as the Altamaha Grit (Harper 1906). Harper (1906) stated that only 0.02% of this region was composed of "sand-hill ponds," whereas another 1% consisted of cypress ponds. Most of the land (50%) was considered dry pine barrens, with sandhills constituting another 8%.

*Notophthalmus perstriatus* was described from specimens first collected in the early 1920s during the Cornell University expeditions to the Okefenokee Swamp. In his January 1, 1923 report to the Heckscher Foundation for the Advancement of Research (Grant No. 14), A.H. Wright (1923) mentioned that a unique species of "rare newt" had been collected "in considerable numbers" and that Miss Eleanor Dorn was working on it. Nothing is known concerning Ms. Dorn, and the Wrights never wrote any papers discussing their collections of salamanders (C. Dardia, Cornell University, pers. comm. 1993). Wright and Wright (1932) provide descriptions and photographs of the upland forest on Trail Ridge, including a



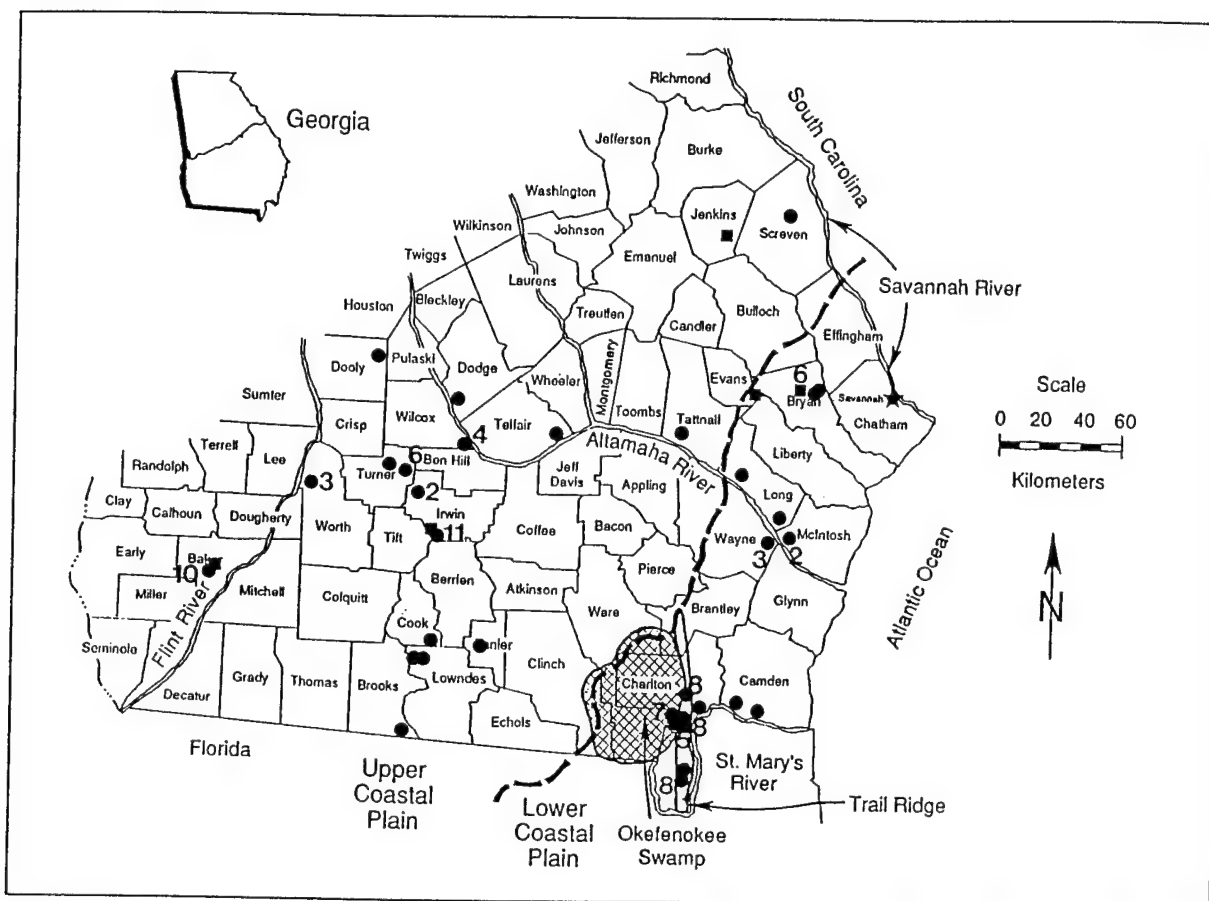
**Figure 1.** Historical and present range of *Notophthalmus perstriatus* in Georgia in relation to the physiographic provinces. Area west of Flint River: Dougherty Plain. Triangle stippling: Tifton Uplands. Small dot stippling: Vidalia Uplands. Slashes: Barrier Island Sequence. Open area centered on Bacon Co.: Bacon Terraces. Dots show historical locations. Triangles show present locations.

photograph of Adam's Pond, which was identified as habitat of the newt.

*Notophthalmus perstriatus* was not described until 1941 by Sherman Bishop (Bishop 1941), one of Wright's students who accompanied him on the first Cornell Expedition in 1912. Mecham (1967) noted only three striped newt locations in Georgia in addition to the type locality, including (1) Lakeland (Lanier Co.), based on a collection in the early 1940s, (2) Bowen's Mill (Wilcox Co.), based on collections by Robert Gordon in 1947 and 1948, and (3) northwest of Valdosta (Lowndes County), based on his own fieldwork (J. Mecham, Texas Tech University, pers. comm. 1992). He apparently overlooked specimens collected in 1953 by A.E. Schwartz from west of Kingsland (Camden Co.) deposited in the Charleston Museum, South Carolina.

In recent years, striped newts were collected in

1982 in Irwin Co. southwest of Ocilla (museum specimens incorrectly listed as originating from Tift Co.). Several sites have been discovered west of Savannah and north of Statesboro on the Coastal Plain, including three on Ft. Stewart (W. Scyle, U.S. Army Corps of Engineers, pers. comm. 1992; Williamson and Moulis 1979) and single locations in Jenkins (collected in 1987) and Screven (last collected in 1975) counties. The Nature Conservancy (TNC) began censuses in Ft. Stewart in 1992 resulting in the discovery of several new breeding ponds (D. Stevenson, TNC, Pembroke, Georgia, pers. comm. 1992, 1993) and one population is under more intensive study (Ben Cash, Georgia Southern University, pers. comm. 1993). Museum specimens are available for Bryan, Camden, Charlton, Evans, Irwin, Jenkins, Lanier, Long, Screven, and Wilcox counties. The objective of this study was to docu-



**Figure 2.** Locations of sites sampled for *Notophthalmus perstriatus*. Dots show sites where newts were not found. Squares show sites where newts were found. Numbers refer to the number of sites sampled in the immediate vicinity.

ment the status of the known sites and to attempt to locate additional sites. The known distribution of striped newts in relation to physiographic province is shown in Figure 1.

## MATERIALS AND METHODS

We attempted to locate all known Georgia striped newt sites based on literature surveys and correspondence; when possible, we contacted the original collectors. In addition, we sampled sites near the historically-known breeding locations; we also studied soils, wetlands, and forestry maps to identify other possible sites. Finally, we consulted with federal, state, and private land management agencies and owners as well as biologists from throughout Georgia and elsewhere to assist in locating additional sites. A newt questionnaire requesting information on the presence of striped newts and potential habitat was sent to all state parks on the Coastal

Plain in Georgia. We contacted various museums to determine their holdings of striped newt specimens from Georgia.

In 1992, we made five field trips to meet with local land managers and contacts, to locate sites, and to become familiar with topography and habitat. No sampling was conducted except for brief dip-netting at Ft. Stewart. Thirteen sampling trips to southern Georgia were made in the springs of 1993 and 1994, and 108 ponds and wetlands were sampled (Fig. 2); a few ponds were sampled on several occasions. Sites in central and southeastern Georgia were visited during the breeding season (January-May) when newts were expected to be in ponds.

Sampling normally was conducted during the day with dip nets, although we used wire-mesh minnow traps to sample sites on Chassers Island in the Okefenokee National Wildlife Refuge on one occasion. Each site was sampled from 15-60+ minutes depending on its size. Data on snout-vent length

(SVL), wet body mass, reproductive condition, and sex of striped newts were recorded following the procedures outlined in Dodd (1993). The presence of other amphibians and their reproductive status (larvae, adults, breeding vs. nonbreeding), fish, reptiles and invertebrates was recorded. Voucher specimens (up to 5/location/visit) were collected and deposited in the United States National Museum of Natural History (USNM), Washington, D.C.

Data on sites included directions to site, county, U.S. Geological Survey (USGS) 7.5' quadrangle, maximum pond depth, dominant plants, status and land use of surrounding habitat, and ownership. Pond pH (measured with a LaMotte model HA pH meter), dissolved oxygen ( $O_2$ ; measured with an Otterbine/Barebo Sentry III oxygen-temperature monitor), relative humidity (measured with a Nester RH pen), and air and water temperature (measured with an Atkins series 396 digital thermometer) were recorded for most sites where striped newts were caught and at ponds where newts recently had been collected during TNC surveys at Ft. Stewart. Striped newts were photographed from each site.

## RESULTS

### Distribution

Striped newts were collected at five widely separated sites, one pond each in Irwin, Jenkins, Baker, and Charlton counties, and at a series of nearby ponds on Ft. Stewart in Bryan and Evans counties (Fig. 2). Newts were not found at previously known breeding ponds on Ft. Stewart (Williamson and Moulis 1979); all recent newt captures have been in ponds identified as a result of recent fieldwork (D. Stevenson and B. Cash, pers. comm. 1993). Collections in Jenkins and Irwin counties reconfirmed previously known sites, and the proximity of several adjacent ponds at the Jenkins Co. site suggests that newts may be present at more than the single pond we sampled. The ponds in Baker and Charlton (Okefenokee National Wildlife Refuge/ONWR) counties represent new locations, and the Baker Co. site extends the known range of *Notophthalmus perstriatus* to west of the Flint River, approximately 110 km further west than the nearest previously known locality.

Although the striped newt was discovered on Trail Ridge and considered abundant by Wright (see above), it was not found at any historical site, including the type locality (Dedge Pond), or at any other

site on Trail Ridge outside ONWR, east of Trail Ridge near or in Folkston, or from the former Camp Pinckney. Trail Ridge has been highly modified since the 1940s. The upland longleaf pine savannah has been replaced by monoculture plantation pine forestry that uses vast clearcuts (Fig. 3) combined



Figure 3. Clear-cut on Trail Ridge, Charlton Co., in former longleaf pine upland known to contain *Notophthalmus perstriatus*.



Figure 4. Small temporary pond in former longleaf pine upland habitat on Trail Ridge west-northwest of St. George, Charlton Co. The pond basin has been logged and severely damaged by heavy mechanized equipment.

with roller chopping and disking as site preparation. Wetlands have been extensively modified; some have been left as isolates whereas many others have been highly modified by ditching, draining, cutting, and plowing (Fig. 4). Only two small stands of upland longleaf pine forest were observed on Trail Ridge from State Route 94 west of St. George to the vicinity of Cypress Siding on U.S. Highway 1, a distance of approximately 40 km.

The historical locations in Lanier and Lowndes counties could not be located because of a lack of precise data. It seems likely that the location of these sites may never be known, especially in light of the extensive habitat modification that has occurred since the 1940s (in Lanier Co.) and 1960s (in Lowndes Co.) in the vicinity of potential habitat, as determined from soils maps (Stevens 1973, 1979). Habitat modification since the 1950s, especially recent forestry, road-construction, and home-building activities, likely eliminated the striped newt population west of Kingsland, Camden Co. The pond at Bowen's Mill Fish Hatchery, where striped newts were collected in 1947 and 1948, was destroyed during hatchery landscape renovation; the striped newt is unknown from other nearby ponds based on collections in the 1940s (R.G. Gordon) and 1990s (present study).

At two historical sites (south of Trader's Hill, Charlton Co. and east of Bascom, Screven Co.), the wetland habitat appeared intact although striped newts were not collected. Newts at these sites were last collected in the 1920s and 1970s, respectively. The site in Screven Co. has undergone physical changes since the 1970s as a result of the introduction of beavers; habitat adjacent to both sites has been modified by forestry operations.

### Newts and Ponds

A total of 26 *Notophthalmus perstriatus* were collected at five ponds: 10 males (31–37 mm,  $\bar{x}$ =34 mm), 6 females (32–40 mm,  $\bar{x}$ =34 mm) and 10 larvae (16–34 mm,  $\bar{x}$ =28 mm). All newts were collected in dip nets; no newts were captured by minnow traps during overnight censuses. Newts were transforming in April at sites in Irwin and Jenkins counties whereas small larvae (16–20 mm SVL) were present on May 24, 1994 at a temporary pond on the ONWR.

Data on pH were available at nine ponds known to presently contain striped newts ( $\bar{x}$ =4.46, range 4.25–4.9). Two readings were available for the Irwin Co. site in 1993: 4.35 in early March and 4.5 in mid-

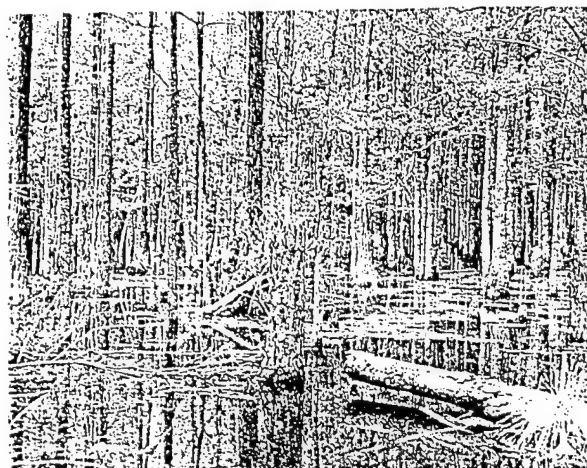


Figure 5. *Notophthalmus perstriatus* breeding pond, Irwin Co.

April. Dissolved O<sub>2</sub> readings were available for three ponds: 8.2 ppm at 13 C (Irwin Co.), 5.5 ppm at 22 C (Evans Co.), and 3.6 ppm at 24 C (Jenkins Co.). A second reading at the Irwin Co. pond in mid-April yielded 8.1 ppm at 17 C. Water temperature ranged from 13–24 C and all ponds were < 1m deep when sampled.

Ponds containing striped newts were dominated by evenly spaced pond cypress (*Taxodium ascendens*) throughout the main portions (Fig. 5). Other plants included swamp blackgum (*Nyssa sylvatica*), sphagnum (*Sphagnum*; important for cover in deeper water), *Hypericum* spp., buttonbush (*Cephalanthus*), fetterbush (*Lyonia*), sedges (*Carex*, *Rhynchospora*), grasses (especially *Andropogon* and *Panicum* spp.), hat pins (*Eriocaulon* spp.), myrtle-leaf holly (*Ilex myrtifolia*), and bladderworts (*Utricularia biflora* and *U. inflata*). All ponds were covered by an intact tree canopy that provided a mosaic of sun and shade on the water surface. No ponds containing striped newts had been logged or directly impacted by timbering practices on adjacent land. One pond (in ONWR) consisted of a deep borrow pit adjacent to an isolated natural pond in undisturbed upland longleaf pine (*Pinus palustris*) forest.

Invertebrates collected with the newts included crayfish (*Procambarus* sp.), dragonfly nymphs (*Anax*, *Libellula*), damselfly nymphs, dipterans, and aquatic hemiptera, including belostomatids, notonectids, and nepids (*Ranatra*). Vertebrates collected or observed included pygmy sunfish (*Elassoma evergladei*), salamanders (*Ambystoma talpoideum*, *Eurycea quadridigitata*, *Notophthalmus virid-*



TABLE 1. Geologic setting of *Notophthalmus perstriatus* localities in Georgia.

County	Underlying Geology	Age	References
Baker	Ocala Limestone	Eocene	1
Jenkins	Neogene Undifferentiated (Kershaw-Plummer Association)	Miocene	2
Irwin, Screven, Wilcox	Hawthorne Foundation	Miocene	3,7
Lanier Lowndes	Hawthorne Foundation (Lakeland-Pelham-Alapaha Association)	Miocene/Pliocene	4, 5, 7
Bryan (in part), Charlton (Trail Ridge)	"Wicomico" Terrace	Pleistocene	1,7
Bryan (in part), Charlton (Folkston, Trader's Hill)	Waycross Terrace	Pleistocene	7
Camden	Penholoway Terrace	Pleistocene	1
	Pamlico Terrace (Pelham-Sapelo Association)	Pleistocene	6,7

References: 1. Georgia Geologic Survey (1976); 2. Brown (1968); 3. Harper (1906); 4. Stevens (1973); 5. Stevens (1976); 6. Rigdon and Green (1980); 7. Huddleston (1988). Terminology follows Huddleston (1988).

*escens*), frogs (*Acris gryllus*, *Hyla femoralis*, *Pseudacris nigrita*, *P. ornata*, *Rana catesbeiana*, *R. clamitans*, *R. grylio*, *R. sphenoccephala*, *R. virgatipes*), a turtle (*Kinosternon subrubrum*), and snakes (*Nerodia* sp.).

## DISCUSSION

### Biogeography

Striped newts in Georgia are found in four physiographic regions (Fig. 1): the Dougherty Plain (Baker Co.), the Tifton Uplands (Irwin, Lanier, and Lowndes counties), the Vidalia Uplands (Jenkins, Screven, and Wilcox counties), and the Barrier Island Sequence (Bryan, Camden, Charlton, Evans, and Long counties). All sites are situated on deep, well-drained, sandy soils (with the possible exception of the Camden Co. site [Rigdon and Green 1980]) and are located adjacent to rivers or large streams. The deep, sandy alluvium and undifferentiated river terraces are of Pleistocene age (Huddleston 1988) although the depositional history and type of soil formation differ from site to site (Table 1).

South and west of the Ocmulgee River and west of the Okefenokee Swamp, the deep sandy terraces that parallel rivers result from erosion, resorting and diagenetic processes. The terraces east of the Okefenokee Swamp and north of the Altamaha River are of marine beach origin (Huddleston 1988),

but also have been modified by stream action. However, the marine terraces are perpendicular to the rivers (Hall 1966) and interconnect with alluvial terraces parallel to rivers. The orientation of the terraces suggests that striped newts may have colonized Georgia from the southwest via two different sandy corridors. One route followed parallel river terraces (via the Alapaha, Flint, and Little Rivers) whereas the other route followed Trail Ridge and other marine terraces parallel to the coast (perpendicular to the river terraces of the Altamaha, Canoochee, Ocmulgee, and Ogeechee Rivers; Fig. 6).

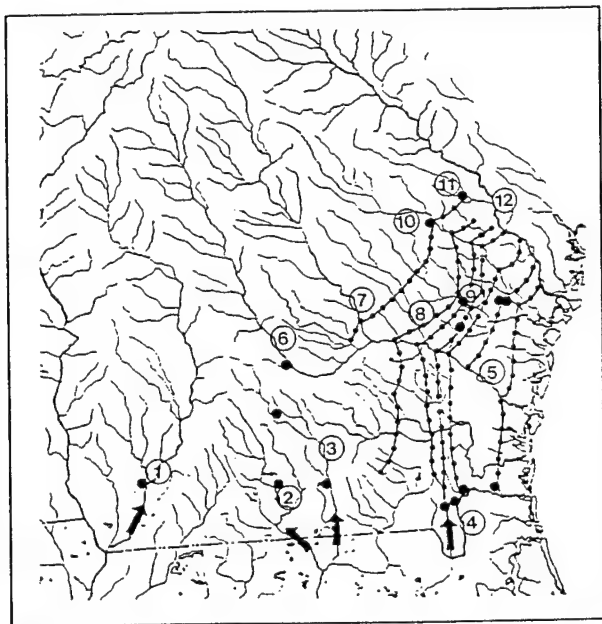
If the above hypothesis is correct, genetic differences may exist between the western striped newt populations (southwest and south-central Georgia, south of Tallahassee, Florida) and the eastern striped newt populations (eastern Georgia and peninsular Florida). The Florida populations of striped newts are found in two geographic clusters separated by a 125 km gap; the Georgia populations appear to be northern extensions of the Florida populations (Franz and Smith 1993). If striped newts evolved 7-8 million years BP from a *Notophthalmus meridionalis*-like western ancestor as suggested by Reilly (1990), the western striped newt localities might have been colonized before the eastern populations. However, both the river and marine terraces are of Pleistocene age (Huddleston 1988) suggesting colonization well after differentiation.



Regardless of how striped newts attained their present distribution, their association with deep, sandy terraces indicates where additional populations might be located. Harper (1906) noted that deep, sandy regions often were associated with the north side of Coastal Plain rivers. The amount of potential habitat is small and scattered, however, and much of the area has been highly modified by human activities or does not contain temporary ponds based on an examination of topographic maps. Examination of soils maps suggests that the following areas might be searched for temporary ponds containing newts: east of Dukes Pond northwest of Millen, Jenkins Co.; east of the Ochopee River north and south of Reidsville, Tattnall Co.; northwest of Claxton, Tattnall Co.; east of Fifteen Mile Creek, Candler Co.; east bank of the Alapaha River in Atkinson and Lanier counties; east of Alapaha, Berrien Co.; east of the Alapaha River south of Stockton, Lanier Co.

#### Conservation Status and Recommendations

*Notophthalmus perstriatus* is known to occur in



**Figure 6.** Location of historical and presently known *Notophthalmus perstriatus* ponds in relation to marine terraces (lines connecting dots) and river drainages. Arrows show possible colonization corridors. 1, Flint River; 2, Little River; 3, Alapaha River; 4, St. Marys River; 5, Altamaha River; 6, Ocmulgee River; 7, Oconee River; 8, Ochopee River; 9, Canoochee River; 10, Ogeechee River; 11, Brier Creek; 12, Savannah River.

only five widely disjunct regions of south Georgia: one pond on timber company property in Irwin Co., one pond (and possibly a few others nearby) south of Scull Creek in Jenkins Co., from a series of ponds on Fort Stewart in Bryan, Evans, and possibly Long counties, one pond on the Okefenokee National Wildlife Refuge in Charlton Co., and one pond on a private ecological reserve in Baker Co. Other populations probably have been extirpated or could not be relocated accurately. Although other populations may be discovered with intensive fieldwork, it seems unlikely that the striped newt is abundant or that its future is secure in Georgia.

There are no baseline data on the striped newt and its habitat within the state of Georgia thus making status assessment somewhat difficult. However, the loss of the longleaf pine (*Pinus palustris*) forest on the coastal plain of Georgia has been dramatic (Boyce and Martin 1993; Stout and Marion 1993; Ware et al. 1993). Concern for the survival of the Georgia coastal plain forest was expressed at least as early as 1906 because of logging, turpentine, and land clearing for agriculture and "civilization" (Harper 1906). Since the 1940s, old-growth longleaf pine forest has been converted to slash (*P. elliotii*) and loblolly (*P. taeda*) pine plantations. In southeast Georgia, longleaf pine declined 36% between 1981 and 1988 to 230,000 acres (Johnson 1988) whereas in southwest Georgia, longleaf pine declined 4% during these same years, to 205,000 acres (Thompson 1988).

Inasmuch as conversion was historically accompanied by the drainage of wetlands, many populations of striped newts, an obligate temporary pond-breeding upland species, may have been destroyed. Without careful attention to habitat management, some surviving populations now may be in jeopardy. Remaining populations are confined generally to one or a few nearby ponds which are islands in a sea of agriculture and monoculture pine plantations (Fig. 7); they are separated by large distances from other populations.

As a result of extensive habitat loss, the native ecosystem of the striped newt is nearly gone, and habitat loss is clearly the foremost threat to the striped newt in Georgia. Considering the proximity of remaining breeding ponds to commercial forestry operations, extreme care needs to be taken to ensure that both breeding ponds and adjacent terrestrial refugia are not disturbed. Buffer zones need to be established around ponds. Forestry practices such as disking, wetland ditching and draining, logging of



**Figure 7.** Aerial photograph of Irwin Co. *Notophthalmus perstriatus* breeding pond (arrow). Striped newts were not found in adjacent ponds. Note the cleared agricultural lands to the north and southwest. Bounded on the west by the Alapaha River, the site is managed using non-destructive forestry practices. Agricultural lands completely surround the site.

wetland hardwoods, and intensive mechanical site preparation are detrimental to newt habitat and must be avoided.

In order to protect the known breeding populations of striped newts in Georgia, habitat conservation plans should be developed to ensure long-term survival. Known striped newt breeding sites need to be monitored for trends in reproductive phenology and population size. Populations should be sampled periodically using standardized amphibian census techniques at set intervals between January and May. Protocols could be worked out based on management agreements. Such monitoring would not be intrusive on landowner operations, especially on federally owned lands. The state of Georgia lists the

striped newt as rare.

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### LITERATURE CITED

- Ashton, R.E. and P.S. Ashton. 1985. *Handbook of the Reptiles and Amphibians of Florida. Part 3. The Amphibians*. Windward Publishing, Miami, Florida.
- Bishop, S.C. 1941. Notes on salamanders with descriptions of several new forms. *Occ. Pap. Mus. Zool. Univ. Michigan*, (451), 1-21.

- Boyce, S.G. and W.H. Martin. 1993. The future of terrestrial communities in the southeastern United States. In: *Biodiversity of the Southeastern United States. Upland Terrestrial Communities* (Ed. by W.H. Martin, S.G. Boyce and A.C. Echternacht), pp. 339-366. J. Wiley & Sons, New York, New York.
- Brown, J.R. 1968. Soil survey of Jenkins County, Georgia. *U.S. Dept. Agric., Soil Conserv. Serv., U.S. Govt. Print. Off.*, Washington, DC.
- Christman, S.P. and L.R. Franz. 1973. Feeding habits of the striped newt, *Notophthalmus perstriatus*. *J. Herpetol.*, 7, 133-135.
- Christman, S.P. and D.B. Means. 1978. Striped newt. In: *Rare and Endangered Biota of Florida, Vol. 3, Amphibians & Reptiles* (Ed. by R.W. McDiarmid), pp. 14-15. University Presses of Florida, Gainesville, Florida.
- Dodd, C.K., Jr. 1993. The cost of living in an unpredictable environment: the ecology of striped newts *Notophthalmus perstriatus* during a prolonged drought. *Copeia*, 1993, 605-614.
- Franz, R. and L.L. Smith. 1993. Distribution and status of the striped newt and Florida gopher frog in peninsular Florida. *Florida Game and Fresh Water Fish Commission*, Tallahassee, Florida. Unpubl. report.
- Georgia Geologic Survey. 1976. Geologic Map of Georgia. 1:500,000. Atlanta, Georgia.
- Hall, R.L. 1966. Pleistocene terraces in Georgia. Unpubl. M.S. Thesis, Department of Geology, University of Florida, Gainesville, Florida, USA.
- Harper, R.M. 1906. A phytogeographical sketch of the Altamaha Grit region of the Coastal Plain of Georgia. *Ann. New York Acad. Sci.*, 17, 1-415.
- Huddleston, P.F. 1988. A revision of the lithostratigraphic units of the Coastal Plain of Georgia. *Georgia Geol. Sur. Bull.*, 104, 1-162.
- Johnson, T.G. 1988. Forest statistics for southeast Georgia, 1988. *USDA For. Serv. Resource Bull.*, SE-104, 53 pp.
- Mecham, J.S. 1967. *Notophthalmus perstriatus* (Bishop). *Cat. Amer. Amphib. Rept.*, 38.1-38.2.
- Reilly, S.M. 1990. Biochemical systematics and evolution of the eastern North American newts, genus *Notophthalmus* (Caudata: Salamandridae). *Herpetologica*, 46, 51-59.
- Rigdon, T.A. and A.J. Green. 1980. Soil survey of Camden and Glynn counties, Georgia. *U.S. Dept. Agric., Soil Conserv. Serv., U.S. Govt. Print. Off.*, Washington, DC.
- Stevens, J.G. 1973. Soil survey of Berrien and Lanier counties, Georgia. *U.S. Dept. Agric., Soil Conserv. Serv., U.S. Govt. Print. Off.*, Washington, DC.
- Stevens, J.G. 1979. Soil survey of Lowndes County, Georgia. *U.S. Dept. Agric., Soil Conserv. Serv., U.S. Govt. Print. Off.*, Washington, DC.
- Stout, I.J. and W.R. Marion. 1993. Pine flatwoods and xeric pine forests of the southern (lower) coastal plain. In: *Biodiversity of the Southeastern United States. Lowland Terrestrial Communities* (Ed. by W.H. Martin, S.G. Boyce and A.C. Echternacht), pp. 373-346. J. Wiley & Sons, New York, New York.
- Thompson, M.T. 1988. Forest statistics for southwest Georgia, 1988. *USDA For. Serv. Resource Bull.*, SE-102, 53 pp.
- Ware, S., C. Frost and P.D. Doerr. 1993. Southern mixed hardwood forest: The former longleaf pine forest. In: *Biodiversity of the Southeastern United States. Lowland Terrestrial Communities* (Ed. by W.H. Martin, S.G. Boyce and A.C. Echternacht), pp. 447-493. J. Wiley & Sons, New York, New York.
- Williamson, G.K. and R.A. Moulis. 1979. Survey of reptiles and amphibians on Fort Stewart and Hunter Army Airfield. Rep. to U.S. Army, Fort Stewart, Georgia (contract DACA 21-77-C-0155).

Wright, A.H. 1923. [Report to] Heckscher Foundation for the Advancement of Research (Grant No. 14). Unpubl. manuscript. A.H. Wright collection, box no. 48, Department of Manuscripts and University Archives, Cornell University Libraries, Cornell University, Ithaca, New York.

Wright, A.H. and A.A. Wright. 1932. The habitats and composition of the vegetation of Okefinokee Swamp, Georgia. *Ecol. Monog.*, 2, 109-232.

## STRIPED NEWT REFERENCES

2/5/99

- Bishop, S. C. 1941. Notes on salamanders with descriptions of several new forms. Occasional Papers Museum of Zoology, University of Michigan 451: 1-21.
- Campbell, H. W. and S. P. Christman. 1982. The herpetological components of Florida sandhill and sand pine scrub associations. Pgs. 163-171 *In*: Scott, N. J., Jr., ed. Herpetological communities. U. S. Fish and Wildlife Service, Wildlife Resources Report Number 13.
- Carr, A. F., Jr. 1940. A contribution to the herpetology of Florida. Biological Science Service, University of Florida Press, Gainesville 3:1-118.
- Christman, S. P. and L. R. Franz. 1973. Feeding habits of the striped newt, *Notophthalmus perstriatus*. Journal of Herpetology 7: 133-135.
- Christman, S. P. and B. D. Means. 1992. Striped newt, *Notophthalmus perstriatus* (Bishop). Pgs. 62-65 *In*: Moler, P. E., ed. Rare and Endangered Biota of Florida, Amphibians and Reptiles. Vol. III. University Press of Florida, Gainesville, Florida.
- Conant, R. and J. T. Collins. 1991. A field guide to reptiles and amphibians of eastern and central North America. Houghton Mifflin Company, Boston, Massachusetts, USA.
- Dodd, C. K. 1992. Distribution of striped newts, *Notophthalmus perstriatus*, in Georgia with a study of age-class structure. Preliminary Report to the U. S. Fish and Wildlife Service, Jacksonville, Florida.
- Dodd, C. K. 1993a. Distribution of striped newts (*Notophthalmus perstriatus*) in Georgia. Report to the U. S. Fish and Wildlife Service, Jacksonville, Florida.
- Dodd, C. K. 1993b. Cost of living in an unpredictable environment: The ecology of striped newts *Notophthalmus perstriatus* during a prolonged drought. Copeia 1993: 605-614.
- Dodd, C.K. <sup>and B. S. Cade</sup> 1998. Movement patterns and the conservation of amphibians breeding in small, temporary wetlands. Conservation Biology 12:331-339.
- Dodd, C. K. and B. G. Charest. 1988. The herpetological community of temporary ponds in north Florida sandhills: species composition, temporal use, and management implications. Pgs. 87-97 *In*: Management of amphibians, reptiles, and small mammals in North America. U. S. D. A. Forest Service General Technical Report RM-166.
- Dodd, C.K. and L.V. LaClaire. 1995. Biogeography and status of the striped newt (*Notophthalmus perstriatus*) in Georgia, USA. Herpetological Natural History 3:37-46.

- Franz, R. and L.L. Smith. 1993. Distribution and status of the striped newt and Florida gopher frog in Peninsular Florida. Final report submitted to Florida Game and Fresh Water Fish Commission , Nongame Wildlife Program, Tallahassee, Florida. 62 pgs. + figures.
- Harris, R. N., R. A. Alford, and H. M. Wilbur. 1988. Density and phenology of *Notophthalmus viridescens dorsalis* in a natural pond. *Herpetologica* 44: 234-242.
- Jensen, J. B. 1995. Survey of potential habitat on Okefenokee National Wildlife Refuge for *Ambystoma cingulatum*, *Rana capito*, and *Notophthalmus perstriatus*. Unpublished report to U.S. Fish and Wildlife Service, Jackson, Mississippi. 19 pp.
- Johnson, S.A. 1998. Natural history and reproductive ecology of the striped newt (*Notophthalmus perstriatus*) in north Florida. Unpublished report to U.S. Fish and Wildlife Service, Jackson, MS. 15 pgs.
- LaClaire, L.V. 1992. Ecology of temporary ponds in north-central Florida. M.S. Thesis, University of Florida, Gainesville, Florida. 175 pgs.
- LaClaire, L.V. 1995. Vegetation of selected upland temporary ponds in north and north-central Florida. *Bulletin of the Florida Museum of Natural History* 38:69-96.
- LaClaire, L.V. 1997. Amphibians in peril: Resource management in the Southeast. Pgs. 307-338 *In*: George E. Benz and David E. Collins, eds. Aquatic fauna in peril: the southeastern perspective, Special Publication 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, GA.
- Means, D. B. 1994. Status of breeding populations of the striped newt, *Notophthalmus perstriatus*, on the Woodville Karst Plain, Leon, Wakulla, and Jefferson counties, Florida. Unpublished report to the U.S. Fish and Wildlife Service, Jackson, MS. ??pp.
- Means, D.B. and R.C. Means. 1998a. Red Hills survey for breeding pond habitat of flatwoods salamander (*Ambystoma cingulatum*), gopher frog (*Rana capito*) and striped newt (*Notophthalmus perstriatus*) in the Tallahassee Red Hills of Leon, Gadsden, and Jefferson counties, Florida, and the Tifton Uplands of Thomas and Grady counties, Georgia. Unpublished report to the U.S. Fish and Wildlife Service, Jackson, MS. 21 pgs.
- Means, D.B. and R.C. Means. 1998b. Distribution of the striped newt (*Notophthalmus perstriatus*) and gopher frog (*Rana capito*) in the Munson Sand Hills of the Florida panhandle. Unpublished report to the U.S. Fish and Wildlife Service, Jackson, MS. 42 pgs.
- Mecham, J. S. and R. E. Hellman. 1952. Notes on the larvae of two Florida salamanders. *The Quarterly Journal of the Florida Academy of Sciences* 15: 127-133.
- Mecham, J. S. 1967. *Notophthalmus perstriatus* (Bishop). Striped newt. *Catalogue American*

Amphibians and Reptiles. 38.1-2.

- Millsap, B. A., J. A. Gore, D. E. Runde, and S. I. Cerulean. 1990. Setting priorities for the conservation of fish and wildlife species in Florida. *Wildlife Monographs* 111: 1-57.
- Moulis, R. A. 1995a. A survey of eastern Georgia for gopher frogs (*Rana capito* ssp.) with notes on the occurrence of *Notophthalmus perstriatus* and *Ambystoma cingulatum*. Unpublished report submitted to the U.S. Fish and Wildlife Service.
- Moulis, R. A. 1995b. A survey of suitable habitat in southwestern Georgia for gopher frogs (*Rana capito* ssp.), striped newt (*Notophthalmus perstriatus*) and flatwoods salamander (*Ambystoma cingulatum*). Unpublished report submitted to the U.S. Fish and Wildlife Service.
- Neill, W. T. 1954. Ranges and taxonomic allocations of amphibians and reptiles in the southeastern United States. Publication of the Research Division of Ross Allen's Reptile Institute 1:75-96.
- Reilly, Stephen M. 1990. Biochemical systematics and evolution of the eastern North American newts, genus *Notophthalmus* (Caudata: Salamandridae). *Herpetologica* 46: 51-59.
- Smith, C. R., S. P. Christman, H. W. Campbell and H. I. Kochman. 1980. Geographic distribution: *Notophthalmus perstriatus* (striped newt). *Herpetological Review* 11:13.
- Telford, S. R., Jr. 1993. Breeding sites for the gopher frog and the striped newt in Ocala National Forest, and the discovery of a possibly undescribed species of frog apparently restricted to the forest. Report to the U. S. Forest Service, Ocala National Forest, Florida.



# HISTORICAL AND BIOLOGICAL ASPECTS OF THE BLACKWATER RIVER IN NORTHWESTERN FLORIDA<sup>1</sup>

WILLIAM L. PETERS AND JEROME JONES

*Florida A & M University, Tallahassee, Florida 32307, USA*

## INTRODUCTION

Mr. W.M. BECK, Jr. has discussed the chemical and physical aspects of the Blackwater River in a paper given previously at this Conference. This paper will discuss the recent historical background of the area which could have influenced the ecology of the Blackwater River area. Further the biology of the river will be discussed from a faunal and ecological view.

## HISTORY

Pleistocene man may or may not have inhabited Northwestern Florida, but radiocarbon datings of artifacts reveal that more than 2,500 years ago human beings were crudely shaping clay in Northwestern Florida. Archaeologists have established five Indian culture periods in Northwestern Florida dating from 600 A.D. to 1650 A.D. The time sequence of these culture periods is based on changes or disappearances of pottery types.

After 1650, the Leon-Jefferson Period resulted from changes made by the influence of the Spanish missions. During the 1730's a group of Choctaw Indians lived in a settlement in Kemper County, Mississippi. This settlement was called Okalusa. Warriors often made inroads into the territory of the Creek Indians and possibly could have explored the Blackwater River area. Okalusa means blackwater (Oka = water, and Lusa = black) and hence the present day name of the river and county. It is not known if the Okalusa group actually named the Blackwater River, or if another group later did so.

The Yuchi (or Euchee) Indians arrived in Northwestern Florida about 1815. This group had been living with the Upper Creeks and their original home was apparently in eastern Tennessee. About 2,000 persons comprised these Indians and several groups lived along the Blackwater River in the 1800's.

Several other names have been given to various portions of the Blackwater River. Apparently, the first foreign discovery of the Blackwater River occurred in 1693 when Don Carlos DE SIGÜENZA Y GÓNGORA, a Mexican scientist, was commissioned to explore the area including the Blackwater River. He named the river Río del Almirante in honor of Admiral Pez, one of the first Spanish explorers in the Pensacola area.

On the PURCELL-STUART map (1778) the upper reaches of the Blackwater River in Okaloosa County are called Fukechatte Leyge. This name is derived from the Creek (Fakka = clay, Chatte = red, and Laiki = site, meaning Red Clay Place). Clearwater Creek is called Weehi-

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<sup>1</sup> Portions of this paper were written during a cooperative agreement between the Southeastern Branch, U. S. Forest Service, and Florida A & M University, Contract No. 18-229.



PLATE I

Blackwater River near Holt, Florida.

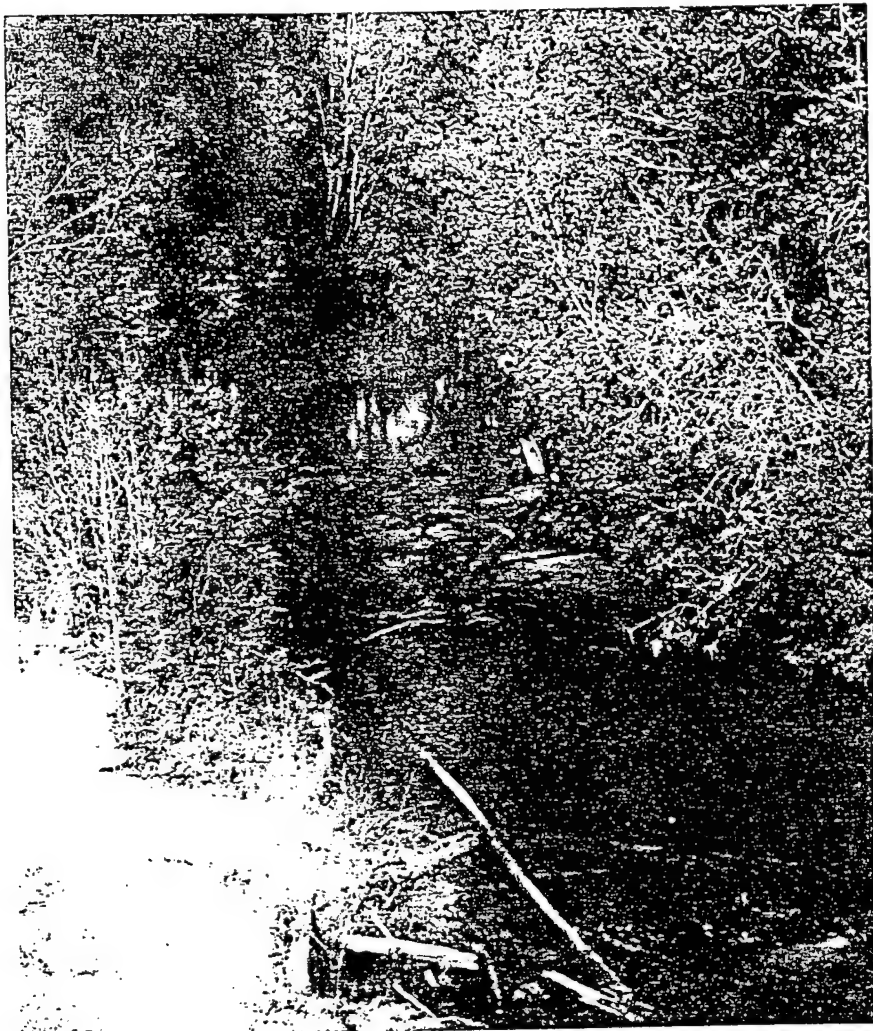


PLATE II

Panther Creek, a tributary of the Blackwater River, near Bradley, Alabama.



a



b

PLATE III

a. Biological station of Florida A & M University near Holt, Florida. b. Mature nymph of *Pseudiron meridionalis*.

heaga on the PURCELL-STUART map. The origin of the name is Creek (Wewa = water, and Haihayaki = clear). Other Creek names include Weekasupka for Coldwater Creek and Weelustee for Pond Creek. This latter name means blackwater, but according to SIMPSON (1956), it was never applied to the Blackwater River proper.

Early in November, 1528, Panfilo de NARVAEZ first explored Northwestern Florida around the Fort Walton Beach area. It was not until 1696 that the Spanish founded a permanent settlement at Pensacola and thus started a 125 year struggle among the Spanish, French, English, Indians, and Americans in the area. During the late 1700's and early 1800's a trail was known from Escambia Bay, near Floridatown, to the upper Chattahoochee River near the present day city of Columbus, Georgia. This trail was an avenue of trade and commerce between the Creeks and the Spanish, and in turn the English. Today the trail is known as the General Andrew Jackson Red Ground Trail and crosses the Blackwater River near the present day Bryant Bridge. On March 10, 1821, Andrew JACKSON was commissioned Governor of Florida and accepted Spanish surrender on July 17, 1821, in Pensacola.

In the years 1808-12, an English ship named the Scotia brought Scottish emigrants to Wilmington, North Carolina. Descendants of these emigrants were the first settlers in the Blackwater River area. Neill McLendon, in 1820, was the first settler and lived near the present day Euchee Anna. More and more Scottish settlers arrived, but Northwestern Florida remained a frontier area during the Indian Wars.

On November 23, 1828, Walton County was formed. Walton County originally embraced the territory lying between the Blackwater River on the west, Choctawhatchee River on the east, Alabama on the north, and the Gulf of Mexico on the south. Later, on November 28, 1842, Santa Rosa County was formed and included territory west of the Yellow River. It was not until June 13, 1915, that Okaloosa County was formed. The headwaters of the Blackwater River lie in Covington County, Alabama (established in 1829), and Escambia County, Alabama (established in 1868).

Since the time of the Spaniards, the Blackwater River area has been known for its pine timber. According to HARPER (1914) the lumber industry of this region reached large proportions early in the state's history. A few sawmills occurred near Pensacola in the 18th century and later in Milton. In 1835 Pensacola exported nearly 4 million feet of lumber and in 1855 about 18 million feet. This was nearly all longleaf pine. Although longleaf has been replaced, for the most part, by slash pine, lumbering is still the major economic feature of the area. Grazing and crops also occur.

The area around the Blackwater River in Florida was acquired in the early 1930's by the U.S. government as a land-use project. Later, in 1938, the Florida Board of Forestry and the U.S. Department of Agriculture executed a cooperative and licensed agreement for a period of fifty years with three automatic successive terms of 15 years each to establish the Blackwater River State Forest. In 1955, the U.S. deeded the forest to the Florida Board of Forestry (now the Division of Forestry, Department of Agriculture and Consumer Services). Almost the entire freshwater portion of the Blackwater River in Florida is within the State Forest. Controlled operations in timber harvesting and naval stores are in the area. Further the State Forest offers excellent hunting, fishing, camping, picnicking, swimming, and hiking.

The headwater tributaries of the Blackwater River lie in Alabama. In 1936, the area of the headwaters became the Conecuh National Forest. The area is entirely protected and offers multiple use as does the Blackwater River State Forest.

In Florida, the Blackwater River State Park is managed by the Division of Recreation and Parks. The park is located along the river in a forest area north of Harold, Florida.

In 1936, the Game and Fresh Water Fish Commission developed the Holt Fish Hatchery which is located north of Holt, Florida. The hatchery supplies millions of fingerling bass and bream for distribution in Florida streams and lakes, and for stocking in private ponds. At present, the hatchery is taking part in the state's striped bass program.

The Game and Fresh Water Fish Commission and Florida A & M University jointly established in 1970 a biological station on Lake Carr (Plate III fig. a). The station has full facilities to study aquatic biology in the Blackwater River area. Plans are now being made to develop the station for further research and teaching.

#### FLORA AND FAUNA

Five natural types of vegetation occur in the Blackwater River State Forest in Florida and Conecuh National Forest in Alabama, and all five types can be found along or near the Blackwater River and its tributaries. Most areas along the banks have natural vegetation. The five types are :

1. Longleaf Pine — Scrub Oak : Longleaf pine (*Pinus palustris*), from seedling size to mature timber, occurs in flatwoods along with one or several of the following oaks, turkey (*Quercus laevis*), bluejack (*Q. incana*), blackjack (*Q. marilandica*), post (*Q. stellata*), myrtle (*Q. myrtifolia*), live (*Q. virginiana*), or laurel (*Q. hemisphaerica*). Longleaf pine predominates in this vegetation type, considered a fire climax association. Stands of this pine vary from parklike to dense, and the associated ground vegetation consists primarily of wire grass (*Aristida stricta*) with numerous annuals and other plants. The majority of vegetation in the State Forest is of this type.

2. Slash Pine : Slash pine (*Pinus elliottii*) is found naturally in moist or wet areas where fire has been primarily excluded. The type may consist of pure stands of slash pine or be associated with red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa biflora*), sweetbay (*Magnolia virginiana*), pond cypress (*Taxodium ascendens*), bald cypress (*T. distichum*) and other hardwoods. Titi (*Cyrilla racemiflora*), grasses, sedges, and numerous annuals compose the ground cover. Most tree planting in the Blackwater River State Forest has been slash pine. Various soil types have been utilized and the areas of planting include old fields and natural areas prepared by clearing with heavy mechanical equipment.

3. Swamp Hardwoods : This vegetation type occurs in wet or overflow areas on bends in the Blackwater River. Vegetation consists of various species of oaks, blackgum, sweetbay, pond cypress, southern magnolia (*Magnolia grandiflora*), Carolina ash (*Fraxinus caroliniana*), Florida ash (*F. pauciflora*), green ash (*F. pennsylvanica*), and other hardwoods. Various grasses, and aquatic and terrestrial annuals, comprise the ground vegetation.

4. Loblolly Pine—Hardwood : Loblolly pine (*P. taeda*) predominates in this association occurring in fertile upland old fields. The species is associated with several species of oaks, ashes, yellow poplar (*Liriodendron tulipifera*), and other hardwoods.

5. Atlantic White-cedar : Pure stands of this species (*Chamaecyparis thyoides*) are found along the banks of the Blackwater River and its tributaries. Associated species, present in some areas, are sweetbay, bald cypress, and various species of oaks, and slash pine.

HARPER (1941) estimated that 51 % of all vegetation in the western part of the "West Florida Pine Hills" was longleaf pine. With increased planting of slash pine this percentage has decreased.



HARPER further pointed out that about 75 % of the vegetation is evergreen. About 15 % of the shrubs are Ericaceae (azaleas, rhododendrons, huckleberry, and others). The high percentage of evergreens and Ericaceae is probably correlated with soils below average in potassium.

Aquatic plants, common in many Florida rivers, are rare in the freshwater portion of the Blackwater River. Arrowhead (*Sagittaria graminea*), spatterdock (*Nuphar advena*) and pickerelweed (*Pontederia lanceolata*) occur occasionally. Various species of sedges are found in swamp areas. Also species of algae are common in both running and still water, with a red algae of the genus *Batrachospermum* occurring on logs and bridge pilings. In the headwaters of many tributaries are found sphagnum and the pitcher plant, *Sarracenia flava*.

The forest area contains a diverse fauna of mammals, birds and reptiles; however, a detailed faunal list of these animals is beyond the scope of this report. The reader is referred to HALL and KELSON (1959) for mammals, WESTON (1965) for birds, and CARR and GOIN (1955) for reptiles.

The aquatic fauna is greatly diversified in the Blackwater River drainage. Unfortunately, Northwestern Florida has been the forgotten portion of the state in most biological studies. This is especially true for the aquatic invertebrates which give the Blackwater River its biological uniqueness. The species composition of many invertebrate groups is incompletely known. Therefore, the discussion herein is limited to a summary of the aquatic vertebrates and selected groups of aquatic invertebrates. Only a faunal list is published here, leaving to the specialist later detailed study of taxonomy and ecology. Selection of these groups is based on availability of collections, practicality of determinations, and available published reports.

Aquatic mammals appear to be rare in the Blackwater River. River otters may be present in the river, although not confirmed by us. In six years of work, we have seen no sign of beaver or muskrat and apparently no sea mammals migrate into the freshwater portion of the river. Raccoons are often seen along the river.

The aquatic reptiles and amphibians in the Blackwater River drainage are diverse. The following is compiled from CARR (1940) and CARR and GOIN (1955). For many species we have further verified the distribution in the Blackwater River drainage in the past six years. It is of interest that the alligator is now extremely rare in the area and we have never seen one along the river. Those species present in the Blackwater River drainage are: hog-nosed waterdog (*Necturus beyeri*), two-toed amphiuma (*Amphiuma means means*), southern two-lined salamander (*Eurycea bislineata cirrigera*), gulf coast red salamander (*Pseudotriton montanus flavissimus*), southern dusky salamander (*Desmognathus fuscus auriculatus*), common cricket frog (*Acris gryllus gryllus*), green tree frog (*Hyla cinerea cinerea*), bullfrog (*Rana catesbeiana*), bronze frog (*R. clamitans*), common snapping turtle (*Chelydra serpentina serpentina*), common musk turtle (*Sternotherus odoratus*), alligator (*Alligator mississippiensis*), rainbow snake (*Abastor erythrogrammus*), banded water snake (*Natrix sipedon fasciata*), green water snake (*N. cyclopion cyclopion*), brown water snake (*N. taxispilota*), and cotton-mouth moccasin (*Ancistrodon piscivorus piscivorus*).

The fishes of the Blackwater River include various species of the minnows, darters, sunfish, bass, suckers, catfish, and pickerels. It appears (YERGER, personal communication) that the river is important in the subspeciation of darters, minnows, and sunfish. Often various species of salt water fish migrate far up the Blackwater River.

BYRD and MILLER (1964) list the following species of catchable fish in the river: Alabama chubsucker (*Erimyzon tennisi*), bluegill (*Lepomis macrochirus purpureus*), northern large-mouth bass (*Micropterus salmoides salmoides*), warmouth (*Chaenobryttus coronarius*), stump-knocker (*Lepomis punctatus punctatus*), shellcracker (*L. microlophus*), long-ear sunfish (*L.*



*megalotis megalotis*), chain pickerel (*Esox niger*), channel cat (*Ictalurus punctatus*), white catfish (*I. catus*), yellow cat (*Ameiurus natalis*), mudfish (*Amia calva*), spotted sucker (*Minytrema melanops*), striped mullet (*Mugil cephalus*), gafftopsail catfish (*Bagre marinus*), sea catfish (*Galeichthys felis*), and silver trout (*Cynoscion arenarius*). The latter four species occur only in or near brackish water. Since 1964, striped bass (*Roccus saxatilis*) have been introduced in the river.

In Juniper and Sweetwater Creeks BYRD and MILLER (1964) list the following species of catchable fish: northern spotted bass (*Micropterus punctulatus*), southern rock bass (*Ambloplites rupestris ariommus*), stump-knocker, long-ear sunfish, chain pickerel, redbfin pickerel (*Esox americanus*), spotted sucker, blacktail redhorse (*Moxostomis poecilurum*), and Alabama chubsucker.

Following is a list of species of aquatic invertebrates now known to us from the Blackwater River drainage. In all cases the species listed are aquatic insects and, in most cases, the species lists for particular groups are incomplete. The Chironomidae (Diptera) of the Blackwater River are being studied by Mr. W.M. BECK, Jr. who reports that this family is rich in species but poor in number. Perhaps one-fourth of the species are undescribed. Several species of the Ephemeroptera (mayflies) are undescribed. The small number of aquatic Coleoptera (beetles) probably reflects the inadequacy of collecting. Further, several major groups of aquatic insects, such as Hemiptera (bugs), are not listed because collections have not yet been identified.

1. EPHEMEROPTERA	Siphonuridae	<i>Isonychia</i> sp. A. BERNER
	Baetidae	<i>Baetis australis</i>
		<i>B. ephippiatus</i>
		<i>B. intercalaris</i>
		<i>B. spiethi</i>
		<i>B. spinosus</i>
		<i>Callibaetis pretiosus</i>
		<i>Centroptilum viridoculare</i>
		<i>Cloeon rubropictum</i>
		<i>Pseudocloeon punctiventris</i>
	Oligoneuriidae	<i>Homoeoneuria dolani</i>
	Heptageniidae	<i>Stenonema exiguum</i>
		<i>S. interpunctatum</i>
		<i>S. smithae</i>
		<i>Pseudiron meridionalis</i>
	Ametropodidae	<i>Siphloplecton speciosum</i>
	Leptophlebiidae	<i>Habrophlebia vibrans</i>
		<i>Habrophlebiodes brunneipennis</i>
		<i>Leptophlebia intermedia</i>
		<i>Paraleptophlebia volitans</i>
	Ephemerellidae	<i>Ephemerella</i> ( <i>Eurylophella</i> ) <i>trilineata</i>
		<i>E. (Serratella) deficiens</i>
		<i>E. (Attenella) attenuata</i>
	Tricorythidae	<i>Tricorythodes albilineatus</i>
	Behningiidae	<i>Dolania americana</i>
	Ephemeridae	<i>Hexagenia munda marilandica</i>
	Polymitarcidae	<i>Tortopus</i> sp.
	Neophemeridae	<i>Neophemera</i> (s.s.) <i>youngi</i>

	Caenidae	<i>Brachycercus</i> sp. <i>Caenis diminuta</i> <i>C. hilaris</i>
	Baetiscidae	<i>Baetisca becki</i> <i>B. escambiensis</i> <i>B. gibbera</i> <i>B. obesa</i> <i>B. rogersi</i>
2. ODONATA	Lestidae	<i>Lestes vigilax</i>
	Calopterygidae	<i>Calopteryx maculata</i> <i>C. dimidiata</i> <i>Hetaerina titia</i>
	Coenagrionidae	<i>Argia fumipennis fumipennis</i> <i>A. moesta</i> <i>A. tibialis</i> <i>A. sedula</i> <i>A. bipunctulata</i> <i>Enallagma weewa</i> <i>Ishnura prognatha</i> <i>Nehalennia intergricollis</i>
	Gomphidae	<i>Dromogomphus spinosus</i> <i>Gomphus</i> (s.s.) <i>lividus</i> ? <i>G.</i> (s.s.) <i>minutus</i> ? <i>G.</i> ( <i>Gomphurus</i> ) sp. <i>G.</i> ( <i>Stylurus</i> ) <i>ivae</i> <i>G.</i> (S.) <i>laurae</i> <i>G.</i> (S.) <i>townesi</i> <i>Progomphus obscurus</i>
	Aeschnidae	<i>Boyeria vinosa</i>
	Libellulidae	<i>Didymops transversa</i> <i>Macromia georgina</i> <i>Neurocordulia alabamensis</i> <i>N. virginensis</i> <i>Celithemis ornata</i> <i>Erythemis simplicicollis</i> <i>Erthrodiplox connata minuscula</i> <i>Libellula incesta</i> <i>L. flavida</i> <i>Nannothemis bella</i> <i>Pachydiplax longipennis</i> <i>Plathemis lydia</i>
3. PLECOPTERA	Capniidae	<i>Capnia</i> sp.
	Pteronarcidae	<i>Pteronarcys</i> sp.
	Perlidae	<i>Neoperla clymene</i> <i>Perlesta placida</i> <i>Perlinella ephyre</i> <i>P. drymo</i> <i>P. fumipennis</i> <i>Acroneuria ruralis</i> <i>A. arenosa</i>
	Perlodidae	<i>Isoperla</i> sp.

4. MEGALOPTERA	Corydalidae	<i>Corydalis cornutus</i>
		<i>Chauliodes rastricornis</i>
		<i>Nigronia serricornis</i>
5. NEUROPTERA	Sisyridae	<i>Climacia areolaris</i>
6. TRICHOPTERA	Philoptamidae	<i>Chimarra florida</i>
		<i>C. socia</i>
	Hydropsychidae	<i>Hydropsyche ellisoma</i>
		<i>H. incommoda</i>
		<i>H. orris</i>
		<i>Cheumatopsyche analis</i>
		<i>C. pasalle</i>
		<i>C. petersi</i>
		<i>C. pinaca</i>
		<i>Macronema carolina</i>
	Limnephilidae	<i>Pycnopsyche indiana</i>
		<i>P. scrabripennis</i>
	Calamoceratidae	<i>Anisocentropus pyraloides</i>
		<i>Ganonema americanum</i>
	Leptoceridae	<i>Leptocella candida</i>
		<i>L. pavidia</i>
		<i>Athripsodes cancellatus</i>
		<i>A. nephus</i>
		<i>A. protonephus</i>
		<i>A. tarsipunctatus</i>
		<i>A. transversus</i>
		<i>Oecetis inconspicua</i>
		<i>O. sphyra</i>
		<i>Micrasema</i> sp.
7. COLEOPTERA	Dytiscidae	<i>Coptolomus interrogatus interrogatus</i>
		<i>Copelatus glyphicus</i>
		<i>Hydroporus carolinus</i>
		<i>H. clypealis</i>
		<i>Enochrus sublongulus</i>
	Hydrophilidae	<i>E. cinctus</i>
		<i>Berosus aculeatus</i>
	Dryopidae	<i>Helichus lithophilus</i>
	Elmidae	<i>Stenelmis convexula</i>
	Gyrinidae	<i>Gyrinus floridensis</i>
		<i>Dineutus discolor</i>

#### THE RIVER

The Blackwater River is a large, white shifting sand river. A visitor to the river first notices the large bars of clean shifting sand with vegetation along the banks down to the water's edge (Plate I). However, to determine the uniqueness of such a river and its fauna, a comparison should be made between the physical and chemical features and the biological features.

Below is a discussion of the major aquatic habitats within the Blackwater River drainage and the insect communities living within the habitats. We chose aquatic insects because

preliminary data are available. It is difficult to list the habitats in any river, as one habitat merges to another. Further, detailed habitat and community studies have just begun. Therefore all habitats discussed below are large, major ones which are easily definable.

The habitats and communities in many tributaries and head waters of the Blackwater River drainage are different than those in the river proper (Plate I-II). Recent collecting indicates that the species of some major groups of aquatic insects differ entirely between particular tributaries and the river. Our discussion of habitats and communities will be confined to the river, with comments only on major specific differences between the river proper and its tributaries.

#### *Shifting sand*

This habitat comprises most of the Blackwater River, except for the margins of the river (Plate I). The water depth ranges from 1 to 15 feet and more during normal flow conditions and the current is fast. The white clean sand of moderate grain is continually shifting and loose. The habitat can be subdivided into areas with completely clean sand and areas with sand intermixed with small amounts of buried or top debris. The water carries this debris during heavy runoffs and the two types of areas continually change position in the river. Often large logs are found in the sand areas. In many tributaries and the headwaters, the area of sand is much reduced and the sand becomes packed, apparently due to decreased water current.

The fauna of this habitat is small in number of species. The nymphs of *Pseudiron meridionalis* occur only in the clean shifting sand habitat (Plate III, fig. b). Adults hatch from March to July and the nymphs do not appear in the river until the winter months. The nymphs of *Dolania americana* also inhabit the clean shifting sand and can be collected on the same hand screen sample as *P. meridionalis*. Adults of *D. americana* hatch in late April and the nymphs appear in the river almost immediately. A large percentage of the biomass in clean shifting sand is *D. americana*. Nymphs of *Homoeoneuria dolani* occur in the clean shifting sand in July and the adults emerge in August. None of the three species occur in the tributaries and headwaters where the clean sand is packed.

Larvae of *Paracladopelma* sp. live in clean shifting sand. Little is known about the life history and ecology of this midge.

Nymphs of *Progomphus obscurus* live in shifting sand, especially in areas of buried debris. This dragonfly species seldom is found on the same hand screen sample as the three species of mayflies. The species has also been collected in tributaries with fairly packed sand. Adults hatch in the spring. Often when debris is on top of the sand *Neophemera youngi*, and various species of *Stenonema*, *Baetisca*, and Plecoptera can be found.

#### *Packed sand covered with silt*

This habitat is normally found along the edges of the river between the dry sand bars and the shifting sand habitat. The habitat also exists in areas of many large logs (Plate II). The middle portion of some smaller tributaries is of this habitat. The water depth ranges from less than an inch to less than a foot and the current is slow to standing water. The bottom is packed sand with less than an inch of loose silt on top of it. In some areas considerable debris is present. The habitat is a product of the slow moving current and can be divided into two areas, an area with slow current and an area with no current.

The fauna in the area of slow moving current includes *Gomphus* (*S.*) *ivae* and *G.* (*S.*) *laurae*,

both burrowers in the silt. Along the line between silted sand and clean sand various species of *Baetisca* can be found. In areas with top debris *Neophemera youngi*, and species of *Baetisca*, *Stenonema*, Trichoptera, and Plecoptera occur. The area with no current along sand bars is poor in fauna; however, in areas where small silted pockets are formed species of *Gomphus*, *Ephemera*, *Stenonema*, and Chironomidae are found.

#### *Banks with current*

This major area can be divided into three habitats.

*Banks with vegetation and leaf litter.* These banks rise 2 to 10 feet above the normal water line and occur along bends of the river (Plate I). The water depth along the banks is the deepest in the river and the water current is the swiftest. The banks are composed of alternating layers of leaf litter and silted sand. Above water the banks are covered with grasses and trees; below they contain a heavy network of plant roots. Often the banks become undercut. In the tributaries these banks are not as high, only reaching two or three feet. While this habitat comprises only a small portion of the river, more species of aquatic invertebrates inhabit this area than any other area. Among the mayflies occur *Isonychia*, various species of Baetidae, Leptophlebiidae, and Ephemerellidae, *Stenonema*, and *Neophemera*. Also common are species of Odonata, Megaloptera, Coleoptera, Plecoptera, Trichoptera, Hemiptera, and Diptera.

*Clay lenses without vegetation.* Often in the banks as described above clay lenses occur. These lenses consist of hard packed clay and, except for an occasional root, are bare of vegetation. The nymphs of *Tortopus* sp. burrow into the clay and make U-shaped tubes.

*Small sand banks with trailing grasses.* This habitat sometimes occurs in the river and is common in the tributaries and headwaters (Plate II). Sometimes a small amount of debris can occur. The banks are usually less than a foot high and the water current is moderately rapid. Many of the aquatic invertebrates occurring in the high banks with vegetation and leaf litter also occur in the small sand banks with trailing grasses.

#### *Swamps or Backwaters*

Swamps or backwaters are formed at the mouths of tributaries and seeps along the river and its major tributaries. They are normally found opposite the high banks on river bends and can be of variable size. Water depth ranges from a few inches to a foot and the water is normally still. Aquatic plants include various sedges, algae, and sphagnum. The sedges can be dense or sparse depending on the swamp. The bottom of these areas is composed of fine silt and mud. Often along the edges where water current starts considerable leaf litter can occur.

The mayflies occurring in the swamps and backwaters are *Siphloplecton*, *Hexagenia*, *Caenis*, and sometimes various species of Baetidae, Heptageniidae, and Ephemerellidae. All the other orders of aquatic insects contain representatives living in the swamps.

#### FUTURE

What is the future for the Blackwater River? Today, as more and more rivers become polluted, the flora and fauna disappear. Many are unfit for recreational use. Large sand bottom rivers occur in various localities throughout the world, but few have escaped the pollution of people and industry.

The Blackwater River is one of the few such sand bottom rivers still existing in its natural state for almost its entire length. While the banks of the river are almost entirely protected by state or national forest, the river is receiving increased pressure due to the influx of population. Tourism especially is increasing with the development of roads and recreational facilities.

The State of Florida is considering designating the river as a "Wild River" which will aid in its protection. Further, the International Biological Program is considering the Blackwater River under its unique river program. While these programs will help in preserving the river, we wonder if this is enough? The senior author has studied the Blackwater River for six years. In his work along the river he has been impressed with the concern of many local residents for the river. The future of the river and its preservation and protection depend on the support and awareness of these local persons. Their concern will determine if the conditions described in this paper become history, or a description of the Blackwater River as it was, is, and continues to be.

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#### RÉSUMÉ

##### *Aspects historiques et biologiques de la rivière Blackwater dans le nord-ouest de la Floride*

La deuxième partie de cette étude sur la rivière Blackwater, dans le nord-ouest de la Floride,

concerne les aspects biologiques de cette rivière et contient un bref aperçu de l'histoire récente de la région. On y trouve une description de l'environnement terrestre comprenant les types de végétation. Celle-ci comprend une liste partielle des invertébrés et des vertébrés aquatiques, les communautés aquatiques de la rivière et de ses affluents sont mentionnées. Pour chaque communauté les relations entre les facteurs physiques et les principaux invertébrés et vertébrés de cette communauté sont discutées.

Parmi ces communautés, celle de sable propre et mouvant est la plus unique. Le sable blanc du pleistocène a une granulation de taille moyenne, il est peu tassé et mouvant continuellement. Le sable est propre, à part occasionnellement quelques zones enfouies de débris. Dans le sable mouvant vivent trois espèces d'Éphéméroptères (*Dolania americana*, *Pseudiron meridionalis* et *Homoeoneuria dolani*), une espèce d'Odonatoptère (*Progomphus obscurus*), et une espèce de Chironomidae (*Paracladopelma* sp.). Les trois espèces d'Éphéméroptères ne peuvent vivre que dans les zones de sable propre et mouvant, et en Amérique du nord ces trois genres ne se rencontrent que dans les rivières avec un tel type de sable. La rivière fait partie de ces quelques rivières en Amérique du Nord que l'on trouve encore dans leur état naturel.

#### ZUSAMMENFASSUNG

##### *Historische und biologische Aspekte vom Blackwasser Fluss in Nordwest-Florida*

Der zweite Teil dieses Berichtes über den Blackwasser Fluss in Nordwest-Florida beschäftigt sich mit biologischen Aspekten des Flusses und enthält einen kurzen Bericht über die rezente Geschichte der Gegend. Die terrestrische Umgebung, inclusive Vegetationstypen, ist beschrieben. Eine teilweise Liste von aquatischen Wirbellosen- und Wirbeltieren ist beigelegt, und die aquatischen Assoziationen in dem Fluss und den Seitenflüssen sind gegeben. Für jede Assoziation ist eine Diskussion der wichtigsten Wirbellosen- und Wirbeltiere und deren Zusammenhang mit den physikalischen Faktoren innerhalb der Assoziation beigelegt.

Von den Assoziationen ist die Assoziation des sauberen gleitenden Sandes am eigenartigsten. Der weisse, pleistocene Sand ist mittelfein, locker gepackt und ständig gleitend. Der Sand ist sauber ausser in Gebieten von vergrabenen Abfällen. Innerhalb des gleitenden Sandes leben drei Arten von Ephemeroptera (*Dolania americana*, *Pseudiron meridionalis*, und *Homoeoneuria dolani*), eine Art von Odonata (*Progomphus obscurus*), und eine Art von Chironomidae (*Paracladopelma* sp.). Alle drei Arten von Ephemeroptera können nur in Gegenden von sauberem gleitenden Sand leben, und in Nordamerika werden alle drei Gattungen nur in Flüssen mit solchem Sand gefunden. Der Blackwasser Fluss ist einer der wenigen solcher Flüsse in Nordamerika der im natürlichen Stadium bleibt.

#### REFERENCES

- BECK, W.M., Jr. (1965). The streams of Florida. *Bull. Fla. State Mus., Biol. Sci.* 10: 91-126.
- BREWER, W. (1872). *Alabama: Her History, Resources, War Record, and Public Men from 1540 to 1872*. Barrett and Brown, Montgomery, 712 pp.
- BYRD, K. and P. MILLER. (1964). Florida Fishing Facts. Blackwater River Watershed. *Rep. Fla. Game Fresh Water Fish Comm.*, 7 pp.
- CARR, A.F., Jr. (1940). A contribution to the herpetology of Florida. *Univ. Fla. Publ., Biol. Sci. Ser.* 3(1): 1-118.
- CARR, A. and C.J. GOIN. (1955). *Guide to the Reptiles, Amphibians, and Fresh-Water Fishes of Florida*. Univ. Fla. Press, Gainesville, 341 pp.



- FUNDABURK, E.L. and M.D. FOREMAN. (1957). *Sun Circles and Human Hands. The Southeastern Indians Art and Industries*. Fundaburk, Luverne, 232 pp.
- HALL, R.E. and K.R. KELSON. (1959). *The Mammals of North America*. 2 vols. Ronald Press, New York, 1083 pp.
- HARPER, R.M. (1914). Geography and vegetation of northern Florida. *Ann. Rep. Fla. Sta. Geol. Surv.* 6 : 163-437.
- HUTCHINSON, L.P. (1961). *History of the Playground Area of Northwest Florida*. Great Outdoors Publ., St. Petersburg, 104 pp.
- KURZ, H. and R.K. GODFREY. (1962). *Trees of Northern Florida*. Univ. Fla. Press. Gainesville, 311 pp.
- LEONARD, I.A. (1939). *Spanish Approach to Pensacola, 1689-1693*. Quivira, Albuquerque, 323 pp.
- McKINNON, J.L. (1911). *History of Walton County*. Byrd, Atlanta, 389 pp.
- MORRIS, A. (1967). *The Florida Handbook 1967-1968*. Peninsular, Tallahassee, 536 pp.
- PURCELL, J. (1778). *A Map of the Road from Pensacola in West Florida to St. Augustine in East Florida*. From a survey made by order of the late Hon. Col. John STUART, Esq. H.M. Supt. of Indian Affairs for the Southern District, Colonial office, P.R.O. Florida 54.
- SIMPSON, J.C. (1956). A provisional gazetteer of Florida place-names of Indian derivation either obsolescent or retained together with others of recent application. *Fla. Geol. Surv., Spec. Publ.* 1, 158 pp.
- WELDON, L.W., R.D. BLACKBURN and D.S. HARRISON. (1969). Common aquatic weeds. *Agric. Res. Ser. Agric. Handb.* No. 352 : 1-43.
- WESTON, F.M. (1965). A survey of the bird life of northwest Florida. *Bull. Tall Timbers Res. Sta.* 5 : 1-149.

# CHEMICAL AND PHYSICAL ASPECTS OF THE BLACKWATER RIVER IN NORTHWESTERN FLORIDA

WILLIAM M. BECK, JR.

*Florida A & M University, Tallahassee, Florida 32307, U.S.A.*

## INTRODUCTION

Although it is one of the most interesting streams in Florida, if not in the entire United States, the distinctive qualities of the Blackwater River are not readily apparent upon casual observation. Certainly streams with shifting sand bottoms are widespread within the Southeastern Coastal Plain Province but the shifting sands of the Blackwater are biologically productive; most others are not. Acid, soft, moderately to highly colored waters such as we find in the Blackwater are extremely common in Southeastern United States. But the Blackwater is different. In some aspects it resembles the rain-forest streams of the upper Rio Negro basin that are strikingly low in dissolved electrolytes (FITTKAU, 1964). In other aspects it differs.

Some of the distinctive features of the Blackwater River are known at present, others remain to be discovered. The River is the object of long range and intensive study by the staff of the Laboratory of Aquatic Entomology. Each visit to this stream is most rewarding.

## BLACKWATER BASIN

Blackwater River is a youthful stream that came into existence at the end of the ice age. The stream traverses a number of Pleistocene marine terraces that are composed of very permeable sand. The permeable nature of the terrace sand gives rise to an unusual feature exhibited by many of the streams in the area — steepness of the heads of the tributary streams. The heads remain steep longer than they would otherwise because there is little surface erosion and the headward growth of the streams is caused by perennial springs, which gradually eat back into the upland, never rising above the level of the zone of ground-water saturation.

MUSGROVE *et al* (1965) have described the drainage basin quite adequately. "Blackwater River heads in southern Alabama, north of Bradley. The river enters Florida north of Baker, flows across the northwestern corner of Okaloosa County, and winds southward along the Santa Rosa-Okaloosa county line for a distance of about 4 miles. At Bryant Bridge, at the county line, the river turns to the southwest and is joined by Big Juniper Creek and Big Coldwater Creek, and then continues toward Milton. At Milton it turns southward and flows into Blackwater Bay.

"The basin is well dissected by tortuous stream channels that wind their way through a thick forest of pine and juniper trees. Except during floods, the water is clear and flows in clean channels of sand and gravel.

"The following discussion of streamflow is by tributary basins, proceeding upstream in the following order: Pond Creek, Big Coldwater Creek, Big Juniper Creek, and upper Blackwater River.

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1973. Proceedings of the First International Conference  
on Ephemeroptera, 1970, Tallahassee.

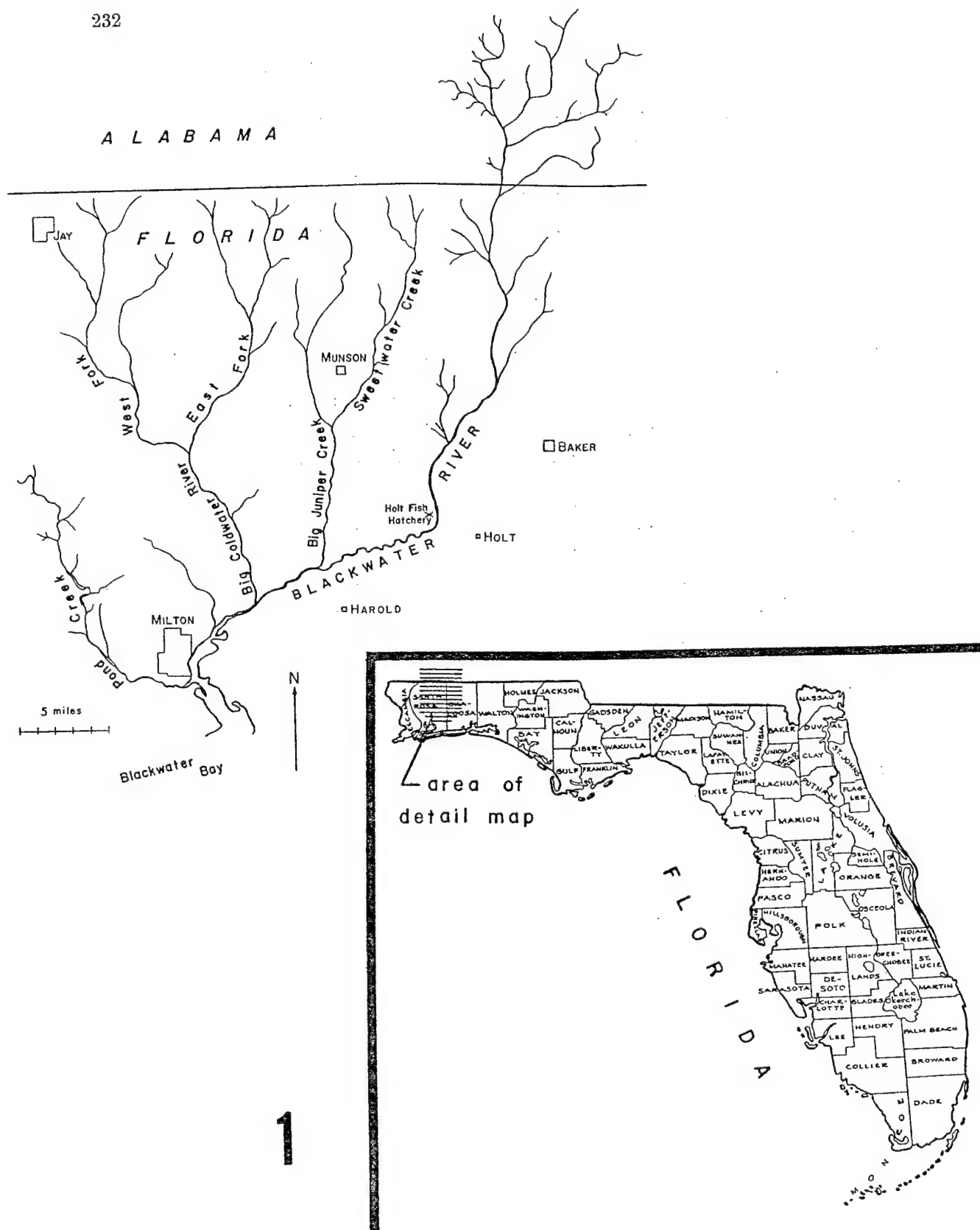


FIGURE 1. Map of the Blackwater River drainage basin, Northwestern Florida.

"Pond Creek drains an area of 88 square miles. The creek flows southward and empties into the Blackwater River just south of Milton. The basin has an elongated shape with relatively short tributaries that drain directly from the steep hills. The land along the basin divide is flat and is from 1 to 2 miles wide. From the flat divide, however, the land slopes steeply to the stream channel.

"Pond Creek has two channels within the lower three-fourths of its flood plain. One of these is the natural channel which is very crooked while the other is a straight channel dug many years ago for transporting logs. The valley slope is steep, with a total fall of about 200 feet from the headwaters to the mouth, a distance of 24 miles.

"The estimated unit runoff from Pond Creek is 1.4 cfs (cubic feet per second) per square mile, which is equivalent to an average flow of 123 cfs from the basin. The minimum daily flow measure at the gauging station during a 4-year period ending 1961 was 43 cfs, or 0.7 cfs per square mile. About 75 percent of the total flow is derived from the ground as base flow and 25 percent is direct runoff by overland flow.

"Big Coldwater Creek is the largest tributary feeding the Blackwater River. The total area drained by this tributary is 241 square miles. All except the smallest streams in the Big Coldwater Creek basin have perennial flows. The average flow from the basin is estimated to be 542 cfs.

"The unit runoff of East Fork and West Fork, the two main tributaries of Big Coldwater Creek, is slightly lower than that of the main creek. The unit runoff from the upper 64 square miles of East Fork is 2.0 cfs per square mile; that from the upper 39.5 square miles of West Fork is 1.9 cfs per square mile; and that from the 237 square miles above State Highway 191, below the confluence of the two forks, is 2.2 cfs per square mile. The intervening drainage area of 133.5 square miles between the two gauging stations on the forks and the gauging station on State Highway 191 has a unit runoff of 2.5 cfs per square mile. About 60 percent of the flow of West Fork Coldwater Creek is base flow and 40 percent is direct runoff from overland flow.

"Streamflow records have been collected for 32 years (1938-70) on Big Coldwater Creek. The gauging station near Milton is located on State Highway 191 and measures flow from 237 square miles. Because of the rolling topography and steep slope of the basin, flood waters drain rapidly. Ground-water seepage sustains the base flows at rather high rates during dry weather.

"The seasonal distribution of runoff in Big Coldwater Creek basin follows very closely the pattern of rainfall. Heavy spring rains cause high runoff, thus March and April have the highest average flows. High intensity rainstorms in July and August cause high peak flows. October is the month of lowest flow.

"Big Juniper Creek, which joins the Blackwater River 5 miles upstream from Big Coldwater Creek, drains 146 square miles. The streambeds in this basin are composed of loosely packed sand and gravel, and the banks are steep and heavily wooded.

"The average flow from the Big Juniper Creek basin is estimated to be 260 cfs, or 1.8 cfs per square mile. Flow was measured at the three sites within the basin: Big Juniper Creek at State Highway 4, near Munson; Sweetwater Creek at State Highway 4, near Munson; and Big Juniper Creek near Harold. Runoff characteristics are similar at these three sites. Slightly over one-half of the flow is base flow; the remaining is direct runoff from overland flow.

"The Blackwater River drains 860 square miles, and discharges an average of 1,490 cfs into Blackwater Bay.

"The lower 6 miles of the Blackwater River channel varies in depth from 10 feet to as much

as 60 feet in holes. At least 6 holes in the lower river are 35 to 60 feet deep. These deep holes trap salt water moving in from the Gulf and could be a source of contamination of the surrounding ground water if large capacity wells are located nearby and pumped heavily enough to cause major drawdowns. The salt front during extreme high tides extends upstream about 6 miles from Blackwater Bay."

#### PHYSICAL FEATURES

Gradient. In Table I are listed gradients and lengths for selected Florida streams. It will be noted that the streams are divided into three groups.

*Table I*  
*Comparison of gradients and lengths of selected Florida streams*

<i>Stream</i>	<i>Gradient Ft. per Mile</i>	<i>Length, Miles</i>
Apalachicola River	0.4	100
Choctawhatchee River	1.4	125
Escambia River	3.8	91.8
St. Johns River	0.1	318
Suwannee River	0.5	245
Blackwater River	3.4	58.4
Big Coldwater River	6.5	27.0
Big Juniper Creek	7.6	24.2
Pond Creek	9.2	21.3
Sweetwater Creek	6.5	18.2
Barrel Branch	117.0	1.5
Bethel Branch	158.1	0.6
Dogwood Branch	100.0	0.5
Yellow Water Creek	112.9	3.1

The first, or top, group consists of the five largest streams of Florida. The St. Johns, which has been referred to as a river, a series of connected lakes, or a fossil lagoon, has the lowest gradient of all, 0.1 ft/mile and a length of 318 miles. The Suwannee is considered a rather swift stream by Florida standards, yet only has an average gradient of 0.5 ft/mile.

The second group consists of the Blackwater River and its main tributaries, all of the latter having steeper gradients than the main stream. A gradient of 3.4 ft/mile for the Blackwater is indicative of the swiftness of the stream and also indicative of the source of energy keeping the shifting sands in almost constant motion.

It is the third group, however, that reveals one of the truly distinctive features of the sand-bottomed streams of the panhandle of Florida. The four examples are for "steepheads", mentioned above. These will be discussed more thoroughly below.

Geological Deposits. The entire Blackwater system is bedded in the Citronelle formation. Although the term "Citronelle formation" is somewhat subject to debate at present, it seems best to retain the term here because of its widespread use in Florida literature.

Table II

*Discharge of the Blackwater River (in cubic feet/second) recorded near Baker, Florida, in 1968*

1968	CFS
MAXIMUM	1660
MINIMUM	73
MEAN	211
JUNE 4, 1969	18,600*

\* 32 year maximum

The following quotation from MARSH (1966) is a very thorough description.

"Type locality. — The Citronelle Formation was named by MATSON (1916) for exposures at the town of Citronelle in northern Mobile County, Alabama, and especially northward along the Mobile and Ohio Railroad for a distance of 3 to 4 miles. At the type locality the formation consists predominantly of light-yellowish brown to reddish-brown, very fine to very coarse, pebbly sand with some white clay as thin layers and pellets scattered throughout. Only the lower part of the formation is present at the type locality, the upper part having been removed by erosion.

Table III

*Water chemistry of the Blackwater River, recorded near Baker, Florida*

	Minimum	Maximum
pH	5.0	6.3
Color, mg/l	10	20
Chlorides, mg/l	2.8	3.2
Hardness, Carbonate, mg/l	2.	6
Hardness, Non-Carbonate, mg/l	0.	3
Total Dissolved Solids, mg/l	15	17
Alkalinity, Bicarbonate, mg/l	2	3
Phosphate (PO <sup>4</sup> ), mg/l	0.00	0.00
Nitrate (NO <sup>3</sup> ), mg/l	9.2	0.6
Dissolved Oxygen, mg/l	6.8	9.7

The Citronelle Formation extends eastward and southward from the type locality into Florida where it underlies all of Escambia and Santa Rosa counties and continues eastward

across the Panhandle for an undetermined distance. How much of the virtually unfossiliferous sand-gravel-clay sequence that is found in the rest of the State should be included in the Citronelle is yet to be resolved. PURI and VERNON (1959) included the "unnamed coarse clastics" of the eastern Panhandle in the Hawthorn Formation of early and middle Miocene Age. COOKE (1945) and PIRKLE (1960) correlate the kaolinitic sands exposed in the central ridge of the peninsula with the Citronelle.

"Thickness. — The thicknesses given here for the Citronelle Formation in Escambia and Santa Rosa counties include the Pleistocene terrace deposits because, as CARLSTON (1950) points out, "it is virtually impossible to differentiate Pleistocene sand and gravel of the marine terraces from the Citronelle sand and gravel." However, the terrace deposits are probably relatively thin, and therefore, their inclusion would not greatly alter the general thickness figures. Together the Citronelle and the terrace deposits range in thickness from about 30 feet at the southern border of Santa Rosa County to about 799 feet in northwestern Escambia County. The combined thickness of these two units in Escambia and Santa Rosa counties is quite variable for two reasons: (1) The base of the Citronelle appears to be an irregular surface of unconformity, and (2) the top of the terrace deposits coincides with an irregular topography of considerable relief.

"Carlston remarks that "the Citronelle formation ... ranges from 40 to 130 feet thick in coastal Alabama, because of pre-Citronelle relief and a general thickening toward the Gulf." MATSON says that the formation may be more than 250 feet thick in southern Alabama and that west of Mobile it may have a maximum thickness of 340 feet. COOKE believes that "in Florida the thickness is probably of the same order of magnitude" as that given by MATSON. The results of the present study do not appear to agree with the thickness figures of either CARLSTON or MATSON, although those obtained for Escambia and Santa Rosa counties are closer to MATSON's figures. Despite the gulfward thickening of the Citronelle in coastal Alabama reported by CARLSTON, just west of the area of this report the Citronelle apparently thins southward (toward the Gulf) as well as eastward in Escambia and Santa Rosa counties, Fla.

"Lithology. — In Escambia and Santa Rosa counties, the Citronelle consists principally of quartz sand which contains numerous lenses, beds, and stringers of clay and gravel. The lithology changes abruptly over short distances.

"The sand is typically light yellowish brown to reddish browns, although some is white or light gray. The grains are mostly angular to subangular and very poorly sorted, ranging from very fine to very coarse. Muscovite is abundant throughout. In places the sand grades into gravel composed of quartz and chert pebbles up to an inch in diameter. A few pebbles of silicified oölitic limestone were noted in samples from the northern part of the area. Elsewhere the sand grades into siltstone and clay. The siltstone is light gray to light yellow and in places contains abundant carbonized plant remains. The clay occurs in lenses as much as 60 feet thick and is chiefly white or gray, although some is lavender, yellow or brown. Fragments of carbonized wood are common in the gray clay. At Molino in Escambia County, clay for making bricks is mined from a lens that is 50 feet thick. Although it is difficult to ascertain the horizontal extend of the clay beds within the Citronelle, they probably range from a few feet to 2 or 3 miles in length.

"A distinctive rock type that occurs in the Citronelle Formation throughout western Florida and southern Alabama is a limonite-cemented sandstone called "hardpan."

"This rock, formed by cementation of sand with iron oxides probably precipitated from ground water, is dark rusty brown and is generally extremely hard, although some may be rather



soft. The "hardpan" most commonly occurs as layers that parallel the bedding of the enclosing sediments. These layers range from a fraction of an inch to 3 or 4 feet in thickness. In places, the "hardpan" is filled with peculiar curving tubular structures of uncertain origin, from a fraction of an inch to several inches in diameter.

"These tubular structures parallel the bedding and are filled with the same loose sand that encloses the "hardpan" layers. Little is known concerning the lateral extent of these hardpan layers, but it is unlikely that any given layer extends for more than a few thousand yards. Escambia and Santa Rosa counties are dotted with hundreds of ponds, many of which probably owe their existence to "hardpan" layers at or near the surface.

"Fossils. — Parts of the Citronelle Formation of the western Panhandle contain abundant remains of trees and other woody plants. This material occurs in two forms : as zones of charcoal and carbonaceous material, and as logs and twigs that have not been carbonized. Samples from well W-4312 in north-eastern Escambia County contain soft black carbonaceous lumps at 190 and 280 feet; in the interval 340-360 feet, an estimated 50 percent of the unwashed samples consists of carbonized wood fragments. A thin, carbonaceous layer may be seen in roadcuts, stream banks, and railroad cuts at many places throughout Escambia and Santa Rosa counties. Whether this actually represents a single, regionally extensive layer or several different layers could not be determined. The thickest carbonaceous zone observed was at an altitude of about 50 feet on the north side of Canoe Creek about 4 miles south west of Century in northeastern Escambia County, where U.S. Highway 29 crosses the creek. Here, a zone of highly carbonaceous clayey earth and gravel containing bits of coal and twigs was exposed in the side of a small artificial drainage cut until later construction work obliterated the exposure. The zone was 2 feet thick, with a sharp but irregular upper contact, and graded downward into sparsely carbonaceous sand at the bottom of the cut. About 8 miles northeast of this locality, a 1-foot carbonaceous zone containing abundant charcoal is exposed at an altitude of about 200 feet along both sides of a deep railroad cut where U.S. Highway 29 crosses the Louisville and Nashville Railroad northeast of Flomaton, Ala. It is not unreasonable to suppose that this bed and the one at Canoe Creek may be the same; if so, it would have a southwestward dip of about 18 feet per mile, which agrees quite well with the regional dip of the Citronelle in Escambia and Santa Rosa counties. Well driller Lehmon ("Tex") SPILLERS (oral communication, April 1961) of Pensacola stated that at Escambia Farms in northern Okaloosa County he drilled through a layer of "burnt wood or charcoal hard as a brick" at a depth of 100-125 feet. He added that most wells in that general area encounter this same carbonaceous zone. These zones of carbonaceous material may have been the result of ancient forest fires.

"The second type of fossil wood in the Citronelle of west Florida is uncarbonized material. At a few places, notably south of Munson in Santa Rosa County, fragments of wood and twigs replaced by limonite were found among lag gravel on the surface of the ground. Of considerably more interest, however, are the numerous logs that well drillers encounter during the drilling of water wells in western Florida. SPILLERS (oral communication, April 1961) reports that he has drilled through many fossil logs in Okaloosa, Santa Rosa, and Escambia Counties, Fla., and in southern Baldwin County, Ala. In the Pensacola area, he says, logs are generally encountered at a depth of about 200 feet and are commonly embedded in a "fine, silty, muddy sand like an old lake bottom." Near Robertsedale in southern Baldwin County, Ala., SPILLERS drilled through a log 3 feet thick between depths of 80 to 100 feet, and "enough pop to fill a couple of barrels" came up the hole, clogging the hole and stopping

up the pump. Other drillers have reported drilling into logs at depths of 50 to 100 feet at various places in the western panhandle.

"Invertebrate Fossils. — CARLSTON (1950) states that "no invertebrate or vertebrate fossils have been found in the Citronelle formation." It is largely for this reason that the age of the formation has never been conclusively established. In Escambia and Santa Rosa Counties, Florida, the great majority of well samples from the Citronelle Formation are nonfossiliferous. However, a few fragments of mollusk shells were noted in samples of the formation from wells in the central and northern parts of the area, at depths ranging from 20 to 300 feet below the surface. These shell fragments were too weathered and broken to permit identification. More significant is the occurrence near the Gulf of abundant fossils in sand and clay beds below about 25 feet. Because of the difficulty of distinguishing the sediments of the Citronelle from deposits formed during the latter part of the Pleistocene, such as the marine terrace deposits, exact correlation of these fossiliferous beds is uncertain. However, these beds may be the marine equivalent of the inland fluvial facies of the Citronelle. Unfortunately, time did not permit identification of the fossils from these beds which might have aided in their correlation."

Steepheads. — The following quotation from VERNON (1942) is the best general discussion of these features that I have found.

"SELLARDS applied the local name "steephead" to unusual amphitheater-shaped valley heads occurring in high sand areas. He attributed their origin to spring sapping along poorly indurated beds underlying more consolidated sands. SHARP agreed with SELLARDS and observed that drainage lines rarely lead from the upland surface into the steepheads. COOKE stated that some of these "steepheads" might result from the stream capture of sink holes.

"Steepheads are natural features and in this area apparently have not resulted from accelerated soil erosion brought about by misuse of land. Most of them are between 100 and 200 feet wide. Steepheads in Holmes and Washington counties occur chiefly at the junction of recent drainage with relatively high land topped by thick deposits of terrace sands. Broad areas of sand absorb large quantities of water, thereby preventing effective run-off. This water emerges at the base of escarpments along the ground water surface as springs, which gradually migrate into the terrace levels. The steepness of the walls of these steepheads depends upon the relative induration of the sediments, and along the Choctawhatchee River south of Hinson's Crossroad, Washington County, they show all gradations from gullies with steep gradients to the typical steephead. The shape of the steephead is also governed by the positions of the springs which produce it. An amphitheater shape is due to a major spring joined by many side, or tributary springs."

#### CHEMISTRY

Due, probably, to its relative isolation, there are rather few chemical analyses available for the Blackwater River. Table III is a summary of analyses from the files of the Florida State Board of Health, the Florida Department of Air and Water Pollution Control, and the United States Geological Survey.

The Blackwater River is chemically a rather typical West Florida sand-bottomed stream (BECK, 1965).

Writing of the area, MARSH (1966) says: "The most important natural resource of economic value in the area is ground water. Escambia and Santa Rosa counties enjoy an abundant

supply of the softest and least mineralized ground water in Florida -- an important factor in industrialization of the area."

#### CLIMATE

The following paragraph from MARSH (1966) summarized the climate of the area adequately.

"Western Florida has a humid, warm-temperature climate. Summers are warm and long, averaging about 80° F at Pensacola, although winds from the gulf make most of the nights comfortably cool. Winters are mild, averaging 55° F with rare cold spells of 15° or 20°. The average annual rainfall is 62 inches. March, July, August, and September are the wettest months, and October and November are the driest. Thundershowers of high intensity are common, with as much as 3 or 4 inches of rainfall during an hour period. Occasional tropical storms and hurricanes blow in from the Gulf of Mexico."

#### CONCLUDING REMARKS

The unusual biological features of the Blackwater River are a reflection of the combined chemical, physical, and geological features.

Chemically the river water is extremely soft and but slightly mineralized. This is due to the ground water flowing through siliceous sands between impervious layers of clay. The effects of this carry over into the stream itself, bedded, as it is, in the same sands and clays, thus having little opportunity to increase mineralization. The water is low in dissolved nutrients, a fact that is reflected in sparse growths of aquatic plants.

It is the physical factors, however, that some of the almost unique features are revealed. Steepheads have been discussed at some length. It is because of these that most of the normal flow of the River is ground water, not runoff water (surface drainage). This results in a tempering effect on extremes of temperature, keeping this stream cooler in summer and warmer in winter than waters of other origin (see BECK 1965 : 110-111 for observed data on this effect).

The shifting white sands in the bed of the River are also unusual in that they appear to support more burrowing organisms than normally found in most other areas of Florida. This needs further investigation.

It is anticipated that we will have an automatic sampler, analyzer and recorder installed in the Blackwater within a few months, giving us 24 hours per day measurement of such factors as water temperature, dissolved oxygen, pH, alkalinity, and conductivity. Perhaps then we will have a much greater understanding of this truly fascinating stream.

#### RÉSUMÉ

##### *Aspects chimiques et physiques de la rivière Blackwater dans le nord-ouest de la Floride*

La rivière Blackwater prend sa source dans le sud de l'Alabama, coule en direction du sud, puis du sud-ouest, à travers les comtés de Okaloosa et de Santa Rosa, vers la baie Blackwater, et se jette dans les baies de l'Est et de Pensacola vers le golfe du Mexique. Son cours d'eau principal a 58,4 miles de long et sa pente moyenne est de 3,4 pieds par mile. La rivière et ses affluents

ont creusé leur lit assez profondément dans des formations du Citronelle, dépôt de sables rougeâtres, d'argile et de gravier remontant au Pleistocène. Cette formation a une épaisseur variant de 30 à 350 pieds et couvre à peu près 860 miles carrés en Floride et en Alabama.

La rivière est un exemple typique de cours d'eau à fond sableux du nord de la Floride, avec un pH légèrement acide (pH 5,0-6,3), une faible concentration en sel (concentration en carbonate 2-6 mg/l), et une faible concentration en particules solides (15-17 mg/l). La teneur en oxygène de ces eaux est assez élevée (6,8-9,7 mg/l) et elles sont faiblement colorées (10-20 mg/l).

A basses eaux la majeure partie des eaux provient des sources constituées par ce que l'on appelle en Floride "steepheads", c'est-à-dire des ravins profonds avec un suintement sur la partie supérieure des parois.

Le débit du cours d'eau principal en 1967 a varié de 73 à 1663 cubic feet par seconde (cfs) avec une moyenne annuelle de 211 cfs. Le plus fort débit pendant une période de 32 ans d'observation a été relevé le 4 juin 1969 et a atteint à peu près 18600 cfs.

L'un des caractères les plus remarquables de cette rivière est le fond de sable blanc constamment renouvelé, ce qui en fait quelque chose d'unique du point de vue biologique.

#### ZUSAMMENFASSUNG

##### *Chemisches und physikalisches Aussehen des Blackwater Flusses in Nordwest-Florida*

Der Blackwater Fluss entspringt in Süd-Alabama, fließt in einer südlichen dann südwestlichen Richtung durch die Bezirke Okaloosa und Santa Rosa zur Blackwater Bucht, und durch Ost- und Pensacola-Buchten zum Golf von Mexiko. Der Hauptstrom ist 54.8 Meilen lang, und der gewöhnliche Gradient 3.4 Fuss pro Meile. Der Fluss und alle seine Nebenflüsse schneiden ziemlich tief in die Citronelle Formation, eine Pleistocene Ablagerung von rötlichem Sand, Lehm und Kies. Die Formation wechselt in Dicke von 30 bis 350 Füßen und bedeckt zirka 860 Quadratmeilen von Florida und Alabama.

Der Fluss ist ein typisches Exemplar von Sandboden-Flüssen im Pfannenstiel von Florida, ein wenig sauer (pH 5.6-6.3), mit aussergewöhnlich weichem Wasser (Carbonat-Härte 2-6 mg/l) und schwacher Festkörperlöslichkeit (15-17 mg/l). Er ist gut mit Sauerstoff durchzogen (6.8-9.7 mg/l) und hat eher wenig Farbe (10-20 mf/l).

Das meiste langsam fliessende Wasser hat seinen Ursprung in Quellen, die in Florida "steep-heads" (Steilköpfe) genannt sind. Diese sind tiefe Einschnitte mit Sickerungen aus dem "head" (Kopf).

Entleerung des Hauptstromes in 1967 variierte von 73 zu 1663 Kubic-Fuss pro Sekunde (cfs), ein Durchschnitt von 211 cfs in Jahr. Die grösste Entleerung in 32 beobachteten Jahren kam am 4. Juni 1969, und war 18,600 cfs.

Eine der hervorstechendsten Merkmale dieses Flusses ist der stets wechselnde weisse Sandboden, welcher für die biologische Einmaligkeit verantwortlich ist.

#### REFERENCES

- BECK, W.M., Jr. (1965). The streams of Florida. *Bull. Fla. State Mus., Biol. Sci.* **10**: 91-126.  
 CARLSTON, C.W. (1950). Pleistocene history of coastal Alabama. *Geol. Soc. Amer. Bull.* **61**: 1119-1130.  
 COOKE, C.W. (1945). Geology of Florida. *Fla. Geol. Surv. Bull.* **29**: 1-339.

- FITTKAU, E.-J. (1964). Remarks on limnology of central-Amazon rainforest streams. *Verh. Internat. Verein. Limnol.* **15** : 1092-1096.
- MARSH, O.T. (1966). Geology of Escambia and Santa Rosa Counties, western Florida Panhandle. *Fla. Geol. Surv. Bull.* **46** : 1-140.
- MATSON, G.C. (1915). The phosphate deposits in Florida. *U.S. Geol. Surv. Bull.* **604** : 1-101.
- , (1916). The pliocene Citronelle Formation of the Gulf coastal plain. *U.S. Geol. Surv. Prof. Paper.* **98** : 167-192.
- MUSGROVE, R. H., J.T. BARRACLOUGH and R.G. GRANTHAM. (1965). Water resources of Escambia and Santa Rosa counties, Florida. *Fla. Geol. Surv., Rep. of Invest.* **40** : 1-102.
- PIRKLE, E.C. (1960). Kaolinitic sediments in peninsular Florida and origin of the Kaolin. *Econ. Geol.* **55** : 1382-1405.
- PURI, H.S. and R.O. VERNON. (1960). Summary of the geology of Florida and a guidebook to the classic exposures. *Fla. Geol. Surv. Spec. Publ.* **5** : 1-255.
- VERNON, R.O. (1942). Geology of Holmes and Washington Counties, Florida. *Fla. Geol. Surv. Bull.* **21** : 1-96.

## FEEDING HABITS OF THE PREDACEOUS NYMPHS OF *DOLANIA AMERICANA* IN NORTHWESTERN FLORIDA (EPHEMEROPTERA : BEHNINGIIDAE)

Philip T. P. TSUI\* & Michael D. HUBBARD

Laboratory of Aquatic Entomology, Florida A & M University, Tallahassee, Florida 32307 USA

\* Present Address: Mobil Oil Canada, Ltd., Environmental Planning Management Dept., Box 800, Calgary, Alberta T2P2J7, Canada

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### Abstract

Feeding habits of nymphs of the predatory mayfly *Dolania americana* Edmunds & Traver in northwestern Florida were examined during 1971 and 1972. Larvae of Chironomidae (Diptera) formed the bulk of prey items. The size of the predaceous *D. americana* nymphs was correlated with the size of chironomid prey taken. Differential microhabitat utilization allows partition of prey resources with the other major predator species present. The relationship between predator and prey biomass throughout the year is discussed.

### Introduction

During a long-term study of the sand burrowing mayfly, *Dolania americana* Edmunds & Traver, in the Blackwater River, northwestern Florida, we discovered that its nymphs are carnivorous. Predatory feeding is relatively uncommon among the predominately detritivorous-herbivorous order Ephemeroptera and we felt that the feeding habits of *D. americana* merited further investigation. The objectives of the present study were: to determine the nature of the food (prey) consumed by the nymphs of *D. americana*; to determine whether food consumption showed seasonal variations; to determine the size relationship between the nymphs of *D. americana* and their prey, if any; and to examine resource partitioning among macroinvertebrate predators in the Blackwater River.

*Dolania* is a monotypic genus of the family Behningiidae which also contains the Palaearctic genera *Behningia* Lestage, with three species, and *Protobehningia* Tshernova, with one species. *Dolania americana* is known from northwestern Florida, southwestern Louisiana, and the Savannah River drainage in Georgia and South Carolina. Further general biological and zoogeographic data on *D. americana* can be found in Peters & Peters (1977). Nymphs examined in this study were collected from two sampling stations on the Blackwater River. Both sites were located in the vicinity of the Florida A & M University Biological Field Station near Holt, Okaloosa County, Florida. The physical and chemical characteristics of the Blackwater River were described by Beck (1973), and the flora and fauna were discussed by Peters & Jones (1973).

### Methods

Nine collections of *D. americana* nymphs were made between June, 1971, and May, 1972, in which a total of 208 nymphs were dissected for gut analyses. Each nymph examined for gut contents was split meso-ventrally and the entire gut was removed and spread in a drop of CMC-10 (Turttox) mounting medium on a standard microscope slide. The entire gut was examined and the contents enumerated. Size of the prey organisms was determined (in the case of dipteran larvae, the length of the head capsule was measured), and the size of the *D. americana* nymphs was measured by the interorbital distance (shortest distance between the eyes).

Estimates of chironomid (Diptera) population densi-

ties at the study areas were made in the months of February, March, and April, 1974. Five one-litre sand samples were taken at hazard each month from the river bottom, preserved in ethanol, and stained with Rose Bengal (100 mg l<sup>-1</sup> preservative). The entire sample was examined and the total number of dipteran larvae in each litre of sand was determined.

Sand particle size distribution was examined by running a transect perpendicular to the shore and taking periodic bottom samples. The samples were then processed through standard soil sieves, separated into size-classes, air-dried, and weighed, and percentage composition was calculated.

Horizontal and vertical distribution of macroinvertebrate predators was examined by taking periodic samples along a transect perpendicular to the shore. The samples were examined and the density and kind of predators present were determined.

## Results and discussion

In the Blackwater River nymphs of *D. americana* are found burrowing in about the top five centimetres of clean, shifting sand. The shifting sand biotope is one of the major habitats found in the river and occupies a great majority of the river bottom. The sand is loose and continuously shifting with grain sizes mostly in the range of 0.25-1.0 mm. Morphologically, the nymph is well adapted for burrowing in this substrate and has evolved various protective structures to counteract the molar action of the shifting sand grains (Edmunds & Traver, 1959). Preliminary studies indicated that *D. americana* has primarily a univoltine life cycle in the Blackwater River, and nymphs are present in the river throughout the year (Fig. 1). Emergence occurs in late April to May (Peters & Peters, 1977). A smaller cohort of *D. americana* nymphs in the Blackwater River apparently does not emerge the first year but remains in the river until the following spring. The reasons for this dichotomy remain unknown.

Other predators coexist with *D. americana* in lesser densities in the shifting sand biotope of the Blackwater River. The two major competitors of *D. americana* are the dragonfly *Progomphus obscurus* (Rambur) (Odonata : Gomphidae) and the mayfly *Pseudiron meridionalis* Traver (Ephemeroptera : Heptageniidae). Preliminary study indicated that although a dietary overlap occurs among these three carnivores, partitioning of resources and a lessening of potential competition is

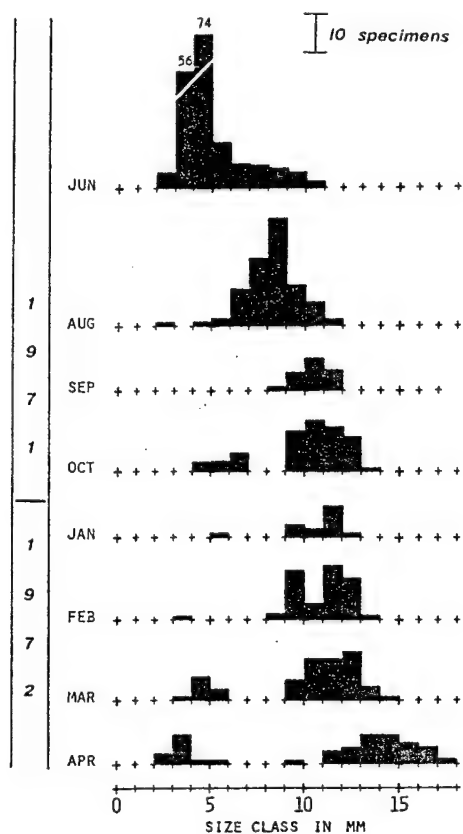


Fig. 1. Seasonal size (body length) distribution of *Dolania americana* nymphs in the Blackwater River.

achieved through differential microhabitat utilization. In contrast to the burrowing habit of *D. americana* and *P. obscurus*, the nymphs of *P. meridionalis* occupy the surface of the sand, not burrowing beneath the substrate. In addition to this vertical partitioning, horizontal partitioning also occurs. Nymphs of *P. obscurus* burrow mostly at the peripheral areas of the stream, whereas *D. americana* nymphs burrow in more submarginal to midstream areas. Samples along transects from the shore reveal that the density of *P. obscurus* lessens with increasing water depth (i.e., distance from shore) and that the density of *D. americana* increases concurrently until almost no *P. obscurus* occur (Fig. 2). Shore transects also indicate that the sand particle size of the substrate likewise increases with increasing water depth, with the percentage of sand particles 0.5 mm or greater in diameter increasing from about 30% at 50 mm depth to 65% at 350-500 mm depth.

Based on gut analyses of *D. americana* nymphs during



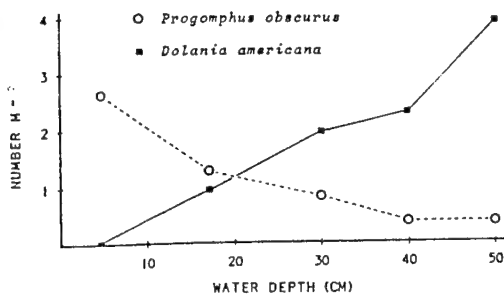


Fig. 2. Density of nymphs of *Dolania americana* and *Progomphus obscurus* along a transect perpendicular to the shore in the Blackwater River (Kennedy Bridge, 16-11-1974).

the study period we discovered that 95% or more of the prey organisms were Chironomidae larvae (Diptera). The overwhelming majority of these chironomid larvae belong to an undescribed species in the subfamily Chironominae. Other prey organisms found in much lesser numbers in gut contents of *D. americana* included microcrustacea, ceratopogonid larvae, nematodes, and occasionally tardigrades. These food organisms are all elements of the interstitial fauna of the sandy river bottom. Keffermüller (1959), in a brief investigation of gut contents of the related species *Behningia lestagei* Motas & Bacesco in the Warta River, Poland, was unable to determine the type of food utilized except that the digestive canal contained traces of 'small grains of sand, diatoms, small pieces of sponge spicules, and an indeterminate organic matter'.

Because chironomid larvae formed the main bulk of the prey items consumed by *Dolania* nymphs we therefore focused our attention on this prey category. Mean numbers of chironomid larvae per litre of sand were 65, 76, and 90 for the months of February, March, and April, 1974, respectively.

For a species to establish and maintain itself in any environment where there is competition, for food or for other resources, certain adaptive mechanisms must have evolved to allow increased utilization of those resources. Macan (1958), Hynes (1961), and Sheldon (1969) have suggested that size variation between individuals of a species can effectively reduce intraspecific competition for food within a population if feeding habits of the individuals are size-dependent. We examined the size range of nymphs of *D. americana* for eight months between June, 1971, and April, 1972 (Fig. 1). Growth rate of the nymphs seemed to be greatest during the first three

months after hatching from the egg stage. Obvious variation in size range of the nymphs occurred throughout the study period. Such size variability within the predator population might be an important adaptive feature if the feeding habits of the predator are size-dependent since this would allow better partition of the available food resources.

Fig. 3 is a graphic presentation of the size relationship between the nymphs of *D. americana* and their chironomid prey. Small larvae were consumed by nymphs of all sizes, as illustrated by the essentially unchanging lower size limits of the prey, while the upper, mean, and median size limits increased with increasing predator size, indicating a size dependent relationship on the upper end of the prey size distribution. The product moment correlation coefficients for predator size and the largest, mean, and median prey sizes were .732, .707, and .817 respectively. All of these values are statistically significant ( $p < .01$ ). Thus, as nymphs of *D. americana* grow larger, they consume an increasingly wider range of chironomid prey size. This fact, coupled with the extensive variation in size range of the *Dolania* nymphs at any one time, results in a greatly lessened prey size overlap. This feeding pattern is similar to that of another aquatic insect predator, *Doro-neuria californica* (Banks) (Plecoptera : Perlidae), reported (as *Acronuria*) by Sheldon (1969).

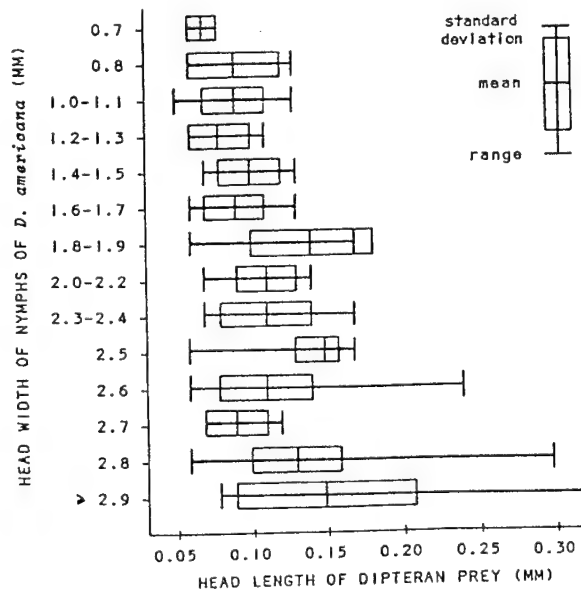


Fig. 3. Distribution of Chironomidae prey size (head capsule length) in relation to *Dolania americana* predator size (interorbital distance) in the Blackwater River.

To obtain an estimate of relative amounts of feeding throughout the year, we felt that the use of biomass as an indicator parameter would be most appropriate. Lacking a direct measure of biomass (because our data were taken in a different form), we have used relative volume (which varies positively with biomass) for this parameter. The relative volume of the prey chironomids was approximated by taking the cube of the head capsule length. That of *D. americana* nymphs was approximated by taking the cube of the total length. Because these approximations of volume are based on two different linear measurements direct relation of them is inappropriate. However, taking the ratio to form a unitless index number (which we call 'prey-predator volume ratio index') is possible. This index number will allow indirect comparison of biomass between sampling periods.

Fig. 4 shows the ratio of the total prey biomass/volume to the total predator biomass/volume for each sampling period. Especially notable is the sharp increase in biomass intake (i.e., prey consumption) during March and the equally sharp decline in April, just prior to emergence of *D. americana* adults. The mean number of prey chironomids per *D. americana* nymph for each sampling period (Fig. 5) again demonstrates the sharp rise in feeding in March and the decline in April prior to emergence. The increase in mean number of prey per predator throughout the life cycle as the size of *D. americana* nymphs increase should also be noted.

The volume ratio index for the median prey individual volume and median predator individual volume for each sampling period is shown in Fig. 6. The ratio holds relatively constant throughout the life cycle except for a high peak in late spring and early summer. This early high prey-predator volume ratio may be explained by the constant lower threshold on prey size (Fig. 3; i.e., size of

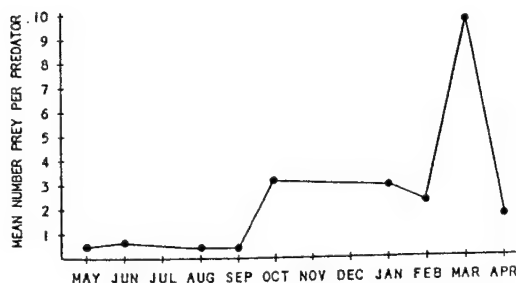


Fig. 5. Mean number of Chironomidae prey per *Dolania americana* from the Blackwater River.

prey chironomids present). This lower threshold size is relatively large compared to the size of early instar *D. americana* nymphs (ca. 3 mm at hatching).

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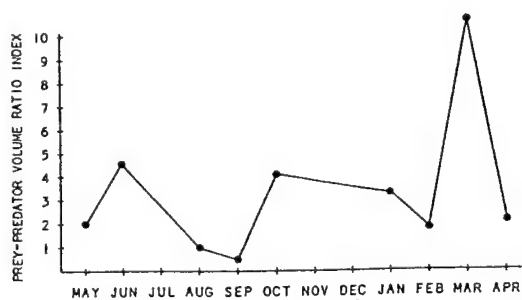


Fig. 4. Ratio index of total Chironomid prey volume per total *Dolania americana* predator volume in the Blackwater River.

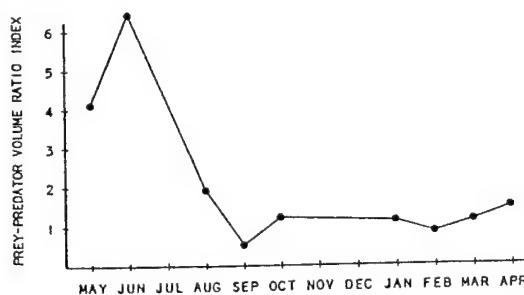


Fig. 6. Ratio index of median Chironomidae prey volume per median *Dolania americana* predator volume in the Blackwater River.

## Summary

1. Prey of *Dolania americana* consisted primarily of larval Chironomidae (Diptera). Microcrustacea, other dipteran larvae, nematodes, and occasionally tardigrades were also found among prey items.

2. The size of the predaceous *D. americana* nymphs was positively correlated with the mean, median, and upper sizes of chironomid prey larvae resulting in a lessened competition for food items of any one size (and thus generally) with the *D. americana* population.

3. A method is developed to allow indirect comparison of biomass between predator and prey.

4. There is a sharp increase in both biomass and number of prey ingested in March and an equally sharp decline in April just prior to emergence of *D. americana*.

5. Differential microhabitat utilization within the Blackwater River allows partition of prey resources with the other major predators present viz., the odonate *Progomphus obscurus* (Rambur) and the mayfly *Pseudiron meridionalis* Traver.

## References

- Beck, W. M., Jr. 1973. Chemical and physical aspects of the Blackwater River in northwestern Florida. Pages 231-241 in Proc. 1st Intern. Conf. Ephemeroptera (W. L. Peters and J. G. Peters, eds.). E. J. Brill, Leiden.
- Edmunds, G. F., Jr. & Traver, J. R. 1959. The classification of the Ephemeroptera. I. Ephemerioidea: Behningiidae. Ann. Entomol. Soc. Am. 52: 43-51.
- Hynes, H. B. N. 1961. The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. 57: 344-388.
- Keffermüller, M. 1959. Nowe dane dotyczące jeteł (Ephemeroptera) z rodzaju *Ametropus* Alb. i *Behningia* Lest. Poznanskie Tow. Przyj. Nauk, Biol. 19 (5): 1-32.
- Macan, T. T. 1958. Causes and effects of short emergence periods in insects. Verh. Intern. Ver. Limnol. 13: 845-849.
- Peters, W. L. & Jones, J. 1973. Historical and biological aspects of the Blackwater River in northwestern Florida. Pages 242-253, plates I-III in Proc. 1st Intern. Conf. Ephemeroptera (W. L. Peters and J. G. Peters, eds.). E. J. Brill, Leiden.
- Peters, W. L. & Peters, J. G. 1977. Adult life and emergence of *Dolania americana* in northwestern Florida (Ephemeroptera: Behningiidae). Intern. Rev. Ges. Hydrobiol. 62: 409-438.
- Sheldon, A. L. 1969. Size relationships of *Acroneuria californica* (Perlidae, Plecoptera) and its prey. Hydrobiologia. 34: 85-94.

# The Secret Swarm

*In the predawn mass mating of sand-burrowing mayflies, timing is everything*

by William L. Peters and Janice G. Peters

Our first reaction to the bizarre sand-dwelling creature was, "Can this be a mayfly nymph?" We were new to Florida, just starting to collect aquatic insects in the state, and unfamiliar with the sand rivers where we would spend much of the next twenty years. After taking a harder look, we detected a similarity to published drawings of the nymph, or immature stage, of the American sand-burrowing mayfly, *Dolania americana*, known then from just a half dozen nymphal specimens in the Western Hemisphere, and not known at all in the adult stage.

Perhaps the unusual nymph had gone largely unnoticed because sand was thought to be an inhospitable habitat. But nymphs hiding in sand could not explain the even more puzzling absence of adult sand-burrowing mayflies. Although we, too, searched, we failed to find living adults. We did, however, find adult remains in spider webs, and for a time we had to be content with robbing webs for dead mayflies, a poor substitute for observing the living animal.

Early one morning a colleague, Jerome Jones, went insect collecting and saw *Dolania* male and female adults mating, and dying, before sunrise. Synchronized, very rapid, mass mating in the dawn hours would explain why adults had never been collected. Our determination to observe a *Dolania* swarm marked the beginning of our research on the maturation and mating of this mayfly. We found that of the two-year *Dolania* life cycle—one year spent as an egg and most of the second year as a nymph—the adult stage ac-

counts for less than two hours or one thousandth of a mayfly's life span, equivalent in human terms to two days in forty-eight years.

A larval life spent tunneling open-eyed through coarse sand requires some modifications and specializations, and these account for the nymph's unmayflylike appearance. Protective hair patches on large outgrowths on its head give *Dolania* prominent "eyebrows." The middle legs are paddlelike for burrowing, but the front legs are reduced to structures resembling an extra pair of mouthparts, probably to assist this aggressive carnivore in catching sand midge larvae and other prey.

*Dolania* is not rare, but its distribution is spotty and its habitat is limited. Although its range covers the coastal plain from Louisiana to Virginia, this mayfly's nymphs live only in clean areas of undisturbed, shifting sand bottoms of larger streams and rivers that have never suffered serious ecological disruption.

During our first few years of research, our attempts to observe adults (in the three weeks a year they are likely to hatch) were largely hit and miss. On one beautiful morning we would see nothing; then the next morning a huge swarm would appear. In 1973, we organized friends, family, students, visiting professors, and co-workers for shifts of what turned out to be a thirty-five-day *Dolania* watch. Through the cooperation of Florida's Game and Fresh Water Fish Commission and Division of Forestry, we had the use of a field station and study site on the protected Blackwater River.

A participant in a *Dolania* watch gets up at three in the morning to be on the river with equipment by four. The sun rises around six, but the mayflies may begin to emerge up to one and three-quarter hours earlier. The hatch begins when male nymphs swim to the river surface, shed their nymphal skins, and fly to vegetation or sand banks to complete the next stage of life. Mayflies undergo a preliminary winged stage, the subimago, or subadult, before achieving full, winged maturity. In the case of *Dolania* (and a few other mayflies), the female has dispensed with the final molt and is fully mature as a subimago.

Thus, males have one more life history stage than do females, but to mate, males and females have to be together at the same time and place. To accomplish this meeting, males hatch earlier and rush through the subimago as quickly as air temperatures allow, from twenty-three minutes at 50°F to five minutes at 73°F. Males hasten the process further by breaking off their middle and hind legs and taking to the air as soon as their wings are free of the old skin. Without functional legs, males spend the rest of their lives in flight. They patrol aerially about three feet over the river searching for emerging females. Even an hour before sunrise, females coming out of their old skins are visible to males—and streamside naturalists—because of their large wings, which are a consistently bright, reflective white. Pairs form as soon as the females emerge. Often, males fly above emerging females until the females take wing, then mate



*American sand-burrowing mayfly*

Janice G. Peters

immediately. If a male is present when a female emerges, she may not spend more than a few minutes in flight in her entire life. The male approaches from behind and underneath the female, copulates for two to five seconds, then disengages and goes on to search for other females. If no males are present, females fly slowly in an undulating pattern, displaying their wings. We presume this display is intended to catch the attention of any available males; at least, the strategy has that result.

We have found no evidence that females choose their mates; females most likely never even see their mates. And while, theoretically, males should favor females with the largest, most eye-catching wings (everything being equal, the large females carry the most eggs), our records show that males chase the nearest available female. When several males pursue a single female, the male that copulates first is the victor. As soon as the mating pair engages, other males turn away. Thus, in competition among *Dolania* males, the race is to the swift. We speculate that by breaking off the "walking legs" during the subimaginal molt, the male not only hurries the completion of that stage but streamlines his body for faster flight as an imago.

A female begins laying eggs almost immediately after copulation, touching the water with her abdomen and dispersing a few large eggs one at a time, then flying to another spot (sometimes mating a second or third time on the way) to repeat the process. In a short time, she tires, falls into the water, and in death is swept away by the current, releasing any eggs left in her body. Even if they are too weak to fly, as long as females are active and flapping their wings, males will follow them. The eggs fall to the bottom of the river and stick tightly to sand grains.

The swarming orgy lasts for about fifteen minutes as more females emerge, mate, begin egg laying, and are carried away downstream. Then, in fishermen's terms, the hatch is over. Fewer and fewer female bodies are seen drifting downstream, while males continue to fly patrol until they too die, usually around sunrise.



*A male Dolania subadult undergoing its last molt clings to a tree trunk. When the male completes this molt, it will become airborne for the rest of its life.*

David H. Funk

Of our thirty-five days in the field in 1973, many mornings were not fit for man or insect: a few mornings brought just a few mayflies; some brought small hatches; and for a couple of mornings the river rose in a swirl of white wings. Over the years, these data have held: at any particular site, about two-thirds of the *Dolania* that emerge will do so in one morning, but usually in two or three, and there will be a few mornings of smaller hatches. Five mornings a year with hatches large enough for quantification—collection and counting of floating skins and dead mayflies—is the norm.

We were amazed that most males and females emerged, mated, laid eggs, and died within the same few minutes of the same day (or two or three dates) each year. Precise timing was critical. We wanted to understand emergence timing, because environmental and man-made effects on hatches or emergence are impossible to assess when we don't know when or how emergence occurs in the first place. With its highly synchronous swarm, *Dolania* became the perfect experimental animal, and the realization that being able to predict emergence would allow us to sleep late some mornings provided extra incentive.

Seasonal temperature and rainfall data enabled us to estimate late April or early May maturation dates. We discovered that an essential factor for emergence is a daily low water temperature of at least 64°F and that this "threshold" temperature must be in effect the day before, rather than the day of, emergence. On mornings with air temperatures somewhat below 50°F, most molting males died trying to achieve the subimaginal molt. Unmated females flew for a while, wings

waving, until they also died. Clearly, these mayflies could not predict the weather on the day of emergence; the process was seemingly cued by previous events and, once under way, could not be stopped.

When and how was emergence predetermined? Temperature records showed that emergence correlated perfectly with a strong positive increase in water temperatures the previous morning (compared with two days earlier). Weak water temperature changes over the preceding days gave ambiguous results—sometimes no hatch but often a small hatch—and no mayflies emerged when water temperature fell. Afternoon water temperatures played no role in emergence, but whether the cue for a given day was the temperature at time of emergence or the daily low was unclear, since both occurred between dawn and sunrise at our site on the river.

Events in the life of insects often cue to points in the daily fluctuations of light (photoperiod) or temperature (thermoperiod). For *Dolania*, the temperature cues for emergence and the daily timing of emergence might depend on the coldest time of day or on the dawn light. On one date, the first male, followed by a cluster of other males, usually emerged about one and a half hours before sunrise. On another date, males would begin to hatch out some twenty-five minutes later, when dawn light had visibly increased. Female emergence times also varied but not as dramatically. For the early grouping, males appeared before or at the time of astronomical twilight, the "crack of dawn." We once thought *Dolania* were somehow sensitive to this first streak of light, although we could detect no change in the sky overhead. But the theory seemed increasingly improbable considering that these insects were buried in sand at the bottom of a river and that emergence occurred equally under clear or cloudy skies. Nor could we find any relationship between the water temperature and the time of hatch.

We then postulated the existence of an internal biological clock. To test this idea we experimentally manipulated light, temperature, or both to test effects on emergence and were able to reach some



conclusions. When natural temperature cycles were eliminated, *Dolania* nymphs hatched on increasing light, and when light conditions were constant, they hatched at cold temperatures. If temperature and light were both manipulated so that nymphs received no natural indication of daylength, emergence occurred a little later each day. However, experiments were only successful when nymphs had been exposed to the new thermoperiod or photoperiod about a week before emergence. Presumably, timing cues were being set then, because any attempt to manipulate cues in those last few days led to incomplete emergence attempts and death. One factor that directly influenced *Dolania*'s response to experimental water temperature and light fluctuation was the critical 64°F threshold temperature. When light cycles and temperature cycles were experimentally separated (making midafternoon the coldest time of day, for example), nymphs emerged at the time of the coldest temperature when the low water temperature had been below threshold, but they emerged at dawn when low temperatures had remained above threshold. There was an exception: certain nymphs emerged at dawn, no matter under what temperature regime they were reared. These nymphs all came from a different *Dolania* population collected far upstream, where the river was narrow and canopied by trees. There, the daily low temperature came later in the morning and was not associated with dawn light.

*Dolania*'s differing responses can be loosely compared to our experiences with alarm clocks. Critical water temperature acts somewhat like an alarm that rings at the same time each day. Assuming it rings at sunrise, it can reinforce other perceptions of dawn and allow us to anticipate its ring. When the alarm is turned off, an internal rhythm, already established by the alarm, continues for several days, with individual variations. Then, dawn illumination itself becomes a cue. With no alarm and no light, less efficient cues are available, such as the time of coolest temperatures. Finally, in the absence of any cues, another internal biological rhythm is established: in our experiments, *Dolania*



emerged a little later each day. Our experimental results helped us understand early emergences in the river following periods of below-threshold water temperatures and later hatches that occurred after five or more warm days with low temperatures above 66°F.

But what happens if low water temperatures have been above threshold but no light has penetrated to the river bottom? Based on experimental results, we assumed that the mayflies would wait until some light eventually penetrated, until they perceived an increase in water temperatures, or until they could wait no longer (internal clocks). In 1985, road construction caused heavy red clay to wash into the river after storms, turning the normally clear waters muddy and blocking the light from reaching more than a few inches into the water. Emergence times shifted to past sunrise, and mating and oviposition occurred in full daylight when the mayflies are especially vulnerable to predators.

Such combinations of field and experimental data contributed to our understanding of how man-made perturbations can hurt insect reproduction in a river. Since aquatic insects depend on temperature and light to set emergence time, such changes as a drawdown of a dam in days prior to emergence might cause abortive emergence attempts and death, while a factor such as heavy siltation might shift the timing of emergence.

More questions remain. *Dolania* females, but not males, vary in color, with the lightest color forms being the most common and the intermediate forms the rarest. The annual representation of dark forms has varied from 2 percent to 35 percent of the female population. We used

*A male frees itself from its old skin. Molted skin sometimes trails behind for a while as males patrol the stream looking for newly emerged females.*

David H. Funk

a variety of methods to attract and count mayflies and to obtain results that could be analyzed statistically. We know that while dark and light females emerge at the same time, the dark forms, or morphs, are nearly absent from drift nets, are likely to fly farther from the river, and will continue to fly at the site of emergence only if males are absent.

All information is consistent with the hypothesis that the dark females disperse, that is, fly away from their place of emergence, to lay eggs elsewhere. Unlike light morphs, which lay eggs immediately after mating, the dark morphs appear to mate and fly away. From what is known about the behavior of other mayflies, we might expect them to disperse upstream. Sometimes we are rewarded by the sight of the dark morphs floating downstream well after sunrise, but we don't know that these are from the same population. If they are, they have made a one and a half mile round trip. They might also represent another population flying five miles or more from any other direction.

Late arriving dark morphs actively bounce along the water surface with wings raised, in contrast to the light morphs, which flounder shortly after they fall into the water. Still hardy after nearly two hours of adult life, dark morphs long outlive light morphs, which rarely survive more than fifteen minutes unless males are absent. Dark females are not present after every hatch, and large numbers of them are rare. We can only speculate on what is happening. Reproduction is essential, but dispersal is optional and more hazardous where predators abound. We should not expect to see survivors often.

Our Florida data confirm that emergence early in the day furthers mayfly survival by allowing them to mate and lay eggs before most common predators are active. Also, while birds, bats, and dragonflies feed on mayflies on warm mornings, none appear to be very active on cold mornings. Fish, the principal aquatic predators near our study site on the Blackwater River, are not influenced by air temperatures and usually feed whenever *Dolania* swarm. Bernard Sweeney and Robin Vannote of the Stroud Water Re-

search Institute showed that mass hatches served to overwhelm predators (principally beetles in their study stream in South Carolina) with huge numbers of prey; the beetles could not possibly consume enough swarming mayflies to hurt the overall population.

Since the debut of mayflies some 350 to 400 million years ago, their evolution and survival have involved the movement of immature stages into sheltered, specialized aquatic habitats and a reduction in the length of the adult stage. According to George F. Edmunds, Jr., of the University of Utah, and Patrick McCafferty, of Purdue University, the subimago, one of many intermediate stages known from fossil mayflies, has probably persevered as the transitional stage to get insects from the water to the air.

The brief adult life and apparent move toward reproduction in younger stages, called neoteny, is evolving in various ways in ail species of mayflies. All adults lack the functional mouthparts that are found in their fossil ancestors, and the adult digestive system has been totally lost. Reproduction by subimagos occurs in females of several families, and while there are no records of mating in nymphs, there is at least one good record of nymphs forming pairs before emergence.

The neotenic trend in mayfly evolution is apparent in *Dolania*, where the less time spent out of the sand, the better. While long-lived dark female morphs may remain in the population as dispersers, evolution favors (at least numerically) the short-lived lighter forms. Even the short, fast, mass swarms and precise timing that bring adults together inevitably sacrifice part of the population to predators. While our immediate research concerns environmental pressures, we can hypothesize that evolutionary pressures also are at work to move *Dolania* from spectacular adult swarms toward reproduction as nymphs in the relative security of the sand.

*William L. Peters is a professor of entomology and Janice G. Peters is a research assistant in the Department of Entomology and Structural Pest Control at Florida A&M University in Tallahassee.*



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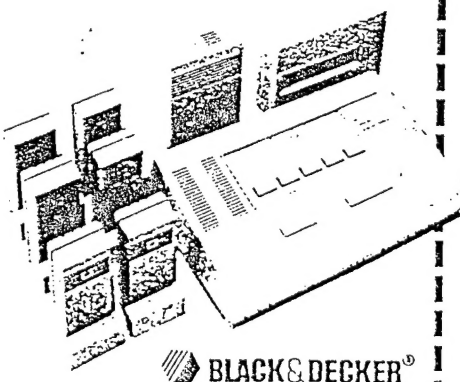
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# THE FOREST

SPRING 1999

CHAMPION INTERNATIONAL'S NEWSLETTER FOR THE CONSERVATIONIST USING OUR LAND

## Hunt of A Lifetime!

by Richard Bruns

Six lucky hunters will win a rare opportunity this September to pursue bull elk, and 51 more will pursue black-tailed bucks in November, on what will be in effect for them a private, 120,000-acre hunting reserve in the shadow of Mt. Rainier, in western Washington State. Champion Pacific Timberlands, Inc. (CPTI), the subsidiary that manages the company's forestlands in the state, is conducting a raffle to award permits for the 1999 Quality Elk & Deer Hunt, which will take place on the Rainier district. "It's unique in this area and was one of the first in the state, when we began the program a few years ago," says Max Ekenberg, vice president of CPTI.

The event is being advertised at sportsmen's trade shows and through the media as "The Hunt of a Lifetime," which is no exaggeration, based on past experience. Last year, three of the five elk hunters got their quarry: the largest bull taken was a 7x7. (A sixth winner did not hunt.) Of 51 deerhunters, 37 were successful, with two 5x4's among those brought in.

"It is not being conducted to control the animal populations," explains CPTI wildlife biologist Jessica Eskow. "It's to raise revenue for our wildlife and recreation programs. We invest a lot of time and money to enhance the habitat, maintain security at the gates, and provide campsites, roads, and communications." Since gates were placed on access roads, poaching, littering, and other destructive activities have been greatly reduced.

The company has an agreement with the state Department of Fish and

Wildlife to provide recreational benefits not only to hunters but also campers, skiers, photographers, and many others, under the Private Landowner Wildlife

dation. The deer population is declining to a more appropriate level for the habitat. The elk population is smaller than the habitat can sustain, and the bull to

## Special hunt raises funds for Champion's recreation program.



Management Area program. CPTI charges a flat access fee to all entrants, regardless of their reason for visiting, throughout the year. CPTI also does extensive data-gathering on the wildlife in the district, such as surveys and lab studies of every animal taken by hunters, dating back to 1987. Habitat is enhanced, for example, by seeding with grasses to produce forage.

About 100 to 150 elk and perhaps 1200 deer live on the district lands, which are forested with Douglas fir, western hemlock, and true firs, with openings where timber has been cut. Eskow says the populations are doing well, though the elk herd in the region has been declining, perhaps due to past overhunting and heavy losses of calves to cougar pre-

cow ratio at 22:100 and calf to cow ratio at 24:100 are lower than desired. A major regional study is under way. No cows are to be taken this year, as part of the effort to enhance population growth; the bull hunt, however, will not be detrimental.

The raffle ticket costs \$15 per entry and is limited to 3,500 entries for the elk hunt and 3,000 for the deer hunt, with a

limit of 30 entries per individual. The winners will get permission to hunt for two weeks, provided they have valid state hunting and transportation tags; to camp on the property; and to use modern firearms, muzzleloaders, or bows. Winners may bring a companion who will not hunt; children under 12 are forbidden; and those between 12 and 17 must be accompanied by a parent or legal guardian. Entries must be postmarked by July 1, and the drawings for both hunts will be held on July 16.

This is the fourth year for the elk hunt and the third year for the deer hunt, Eskow notes. "It's been highly successful every year," she says, "both for the company and the hunters." (See raffle entry on next page.)

## Let the Little Ones Walk

The Champion Wildlife Management has finished its first hunting season under the new forked antler rule. "We had a very successful season" according to Earling Hunter, the Florida Game and Fresh Water Fish Commission wildlife biologist. "The number of deer harvested, average weights and antler size were better than we expected," says Hunter. The forked antler rule is designed to protect more of the yearling buck age class allowing them to grow till the next season. "Next year we should see an increasing trend in the average weight and antler size because of the forked antler rule," Hunter added.

## Have You Hugged Your Hunting Club Officers Today?

Hunting club officers are essential to the success of the hunting club. They are the ones that make sure the details are taken care of to keep your club running. These are special people who take on extra work and responsibility with little or no reward and often bear the brunt of having to manage internal conflicts. The next time you are on your lease, sitting in your stand or just swapping hunting stories with other members, remember the guys who make it possible... and let 'em know you appreciate their efforts.



## A Cooperative Effort for Erosion Control

Volunteers from Champion and The Gulf Coastal Plains Ecosystem Partnership (GCPEP) put the finishing touches on a gully control project on the last Saturday in February. They planted tree seedlings and put in erosion control devices on a major gully that was threatening I-10 and the down stream habitat of the rare Bog frog. Champion is the only private landowner in the GCPEP, a voluntary partnership controlling over 850,000 acres of contiguous ownership from the Conecuh National Forest in South Alabama to Eglin AFB on the Gulf Coast. One of the goals of the partnership is to take a coordinated ecosystem approach to conserving the sensitive and rare components on the landscape.

## Saving Plants,

especially one of the rarest in the state is important to a lot of people and to Champion as part of our commitment to sustainable forestry.

Champion owns and manages the site of a tiny patch of ground that is home to the only known population of the Cooley's meadowrue in Florida. The site is also designated as one of Champion's Special Places in the Forest®, a program that places unique sites in Champion's working forest under protection to manage and preserve the unique qualities of that site. The Florida Nature Conservancy and Champion

recently teamed up to conduct a prescribed fire to remove competing vegetation and to stimulate flowering. If the effort is successful, seeds will be collected in the summer and planted in Champion's Research and Development Greenhouse facility. The seedlings would then be introduced in other suitable habitat to ensure the survival of this rare species.

For questions about Champion's hunting lease program or our forest operations please write to:

**Champion International Corporation**

Hunting Lease Program

P.O. Box 875

Cantonment, FL 32533